# SILAGE MANUAL

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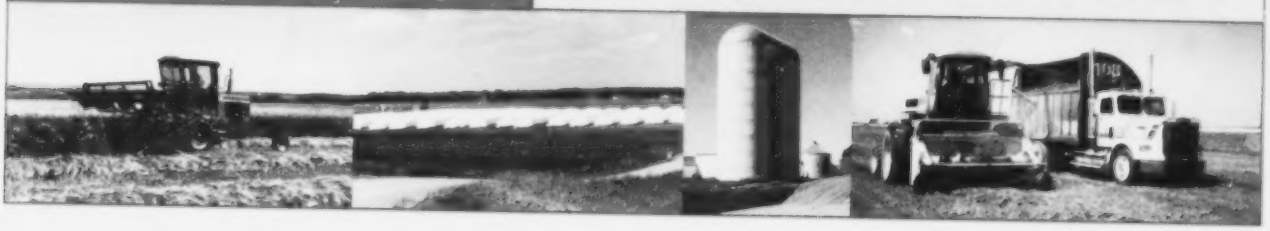

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# Introduction

Silage systems can help producers improve carrying capacities and store nutritional winter feed for livestock. However, each system should be looked at carefully to see if costs balance out against benefits. Looking at the advantages and disadvantages of silage production is a necessary first step.

Well-planned silage systems have the potential to increase carrying capacities substantially, in many cases doubling them. Considerable planning must go into these successful systems. This manual will give you many of the tools necessary to develop and implement your plan.

If you are just starting into silage, read the manual carefully and consider hiring an experienced custom operator to help you get started. Start out slowly and build up your skill level before expanding. Talk to experienced operators and get their suggestions. Can you ever know too much about a topic such as this?

If you are an experienced silage operator, you will also find this manual useful. It provides answers to questions like: How many animals can I feed with this pile? and How do I calculate moisture content? It covers many other points to help fine-tune your operation and increase profitability.

Preserving and storing an adequate and nutritionally suitable winter feed supply is an essential part of livestock production in western Canada. With feed costs making up a major portion of total livestock industry expenses, it is essential that the most efficient and effective method be used. Silage offers the opportunity of consistently putting up high quality feed with a minimum of harvesting losses despite the weather conditions. Timely harvesting will minimize losses, resulting in high quality silage. Properly managed, the ensiling process maintains the quality of the forage crop.

Low quality silage can result from a lack of understanding of the process, poor planning or inadequate or imbalanced equipment, labor or storage facilities. Before making a long-term commitment to put up silage, you will need to estimate the relative merits of various systems, especially total costs, availability of labor, need for consistent high quality feed, how well harvesting utilizes existing equipment and how the whole silaging process can be integrated with other farm operations. When a silage system is selected, it pays to understand the process well and to do it correctly.

## ADVANTAGES OF SILAGE COMPARED TO HAY

The major advantage of silage is that the crop can be harvested when it is ready in almost any weather conditions and put up quickly.

Since there are fewer harvesting losses, more nutrients are harvested per acre compared with most other systems (see Table 23 in the *Silos* chapter). Ensiling permits the use of a wider range of crops including corn, fababeans and sunflowers, which are difficult to preserve by other methods. It offers a practical method of salvaging weedy, hail-damaged, frozen or otherwise damaged crops to produce a palatable and nutritional feed supply.

Silage can be put up and stored in large quantities of uniform quality requiring minimal adjustments to the ration fed. Feeding silage reduces many feeding problems including difficulties with starting cattle on feed, bloat and elimination of dust. It also minimizes the need for feed processing.

## DISADVANTAGES OF SILAGE

The major disadvantages of silage compared with hay are that silage requires more labor and time. However, economies of scale and labor requirements can be met by working with neighbors. Many operators now hire custom operators to chop and haul silage.

Capital costs and total costs per tonne (ton) harvested can be high or low depending on the total tonnage harvested and the system used. Used silage structures have limited market value.

Silage has limited market potential. Silage is heavy, so long distance hauling is inefficient. It must be produced near the location where it will be fed. Transportation of baled silage is somewhat more feasible, but keep in mind that bales start to deteriorate once the plastic seal on the bales has been broken.

Make sure storage and feeding losses don't negate the advantages built up during harvest. Inadequately sealed silage systems can contribute to major storage losses. Some recent research indicates that there are negative

effects from mixing spoiled feed with unspoiled feed during the feeding process. Consider this factor when managing your feed supplies.

Silage production involves some community and environmental considerations. Silage odor is offensive to many people, and this aspect should be considered when choosing storage locations. Silage seepage can contaminate surface and groundwater. Various types of storage can result in seepage. An effort should be made to install a professionally designed collection system and to dispose of the collected seepage in an approved manner. Waste plastic is becoming a major concern. This is an area we have to address more effectively by recognizing this concern and developing recycling programs.

### SILAGE RELATIVE TO OTHER PRODUCTION

Making silage can fit in well with most other farming operations. By ensiling cereals, you reduce the number of acres that must be combined. Early ensiling provides more time to do other fall fieldwork. And, as mentioned, silage offers a way to salvage crops that are useless for other purposes.

Silage crops that are harvested early are better companion crops for perennial forages and pasture than crops left to mature for grain. Reducing seeding rates and nitrogen fertilization rates for the silage crop will result in less competition with the establishing underseeded forage crops.

#### NOTE: DISEASE THREAT

Fusarium head blight, caused by the fungal pathogen *Fusarium graminearum*, is a serious threat to Alberta's crop and feeding industry. Growers and feeders should have grain and cereal forages tested for *Fusarium graminearum* before bringing them into the province. Corn is also a host of this disease, and grain corn can also be infected. For more details, contact Shaffeek Ali (780 422-4909) of the Pest Risk Management Unit of Alberta Agriculture, Food and Rural Development.

# Chapter 1: **Ensiling Process**

Understanding the ensiling process means learning what factors contribute to making good silage. Exposure to oxygen plays a big role. Other factors such as water soluble carbohydrates, buffering capacity, moisture content, microorganisms and fermentation also determine silage quality. Good packing and chopping help the process along.

Silage is the feedstuff resulting from the preservation of green forage crops by acidification. Acidification is the result of the fermentation of the forage in the absence of oxygen.

There are two main phases in the ensiling process. The first is the aerobic phase that occurs in the presence of oxygen (air), and the second is the anaerobic phase that occurs when the oxygen is used up.

**Aerobic phase:** Oxygen is present in the forage as it is placed in the silo. This oxygen is consumed by the living plant material through the process of respiration. Under aerobic conditions, plant enzymes and microorganisms consume oxygen and burn up the plant water-soluble carbohydrates (sugars), producing carbon dioxide and heat.

The length of this phase varies depending on ensiling conditions. It could last for a few hours or as long as several days. During this phase, water-soluble carbohydrates are being consumed and other nutrients are being destroyed. In addition, the heat generated by an extended aerobic phase can raise the temperature of the ensiling forage material sufficiently to cause heat damage to the silage.

Therefore, good silage making practices reduce the amount of time that aerobic microorganisms and oxidizing plant enzymes are able to function. This is accomplished by chopping the silage to a short length, packing it thoroughly, and then quickly and effectively sealing the silo.

**Anaerobic phase:** The anaerobic phase begins when the available oxygen is used up through plant respiration, and aerobic bacteria cease to function. Anaerobic bacteria (bacteria that grow in the absence of oxygen) then begin to multiply rapidly, and the fermentation process begins.

Ideally the anaerobic microorganisms that grow most rapidly will be predominately lactobacilli species, which produce lactic acid from the fermented plant material.

Lactic acid lowers the pH of the silage. Fermentation completely ceases after three to four weeks when the pH becomes so low that all microbial growth is inhibited.

If ensiling procedures are such that lactic-acid-producing bacteria aren't favored, clostridial microorganisms will grow. These organisms use plant water-soluble carbohydrates, lactic acid and protein for growth and produce butyric acid. The quality of silage is greatly reduced if a clostridial type of fermentation predominates.

The foregoing is a very simplistic summary of the ensiling process. In addition to lactobacilli and clostridial microorganisms, silage also contains yeasts, moulds, coliforms, bacilli and propionic-acid-producing bacteria. In addition to using plant sugars as energy sources, silage microorganisms degrade protein to amino acids, amines and ammonia during fermentation. Literally hundreds of fermentation products are formed in addition to lactic and butyric acids.

## FACTORS AFFECTING SILAGE FERMENTATION

The primary factors affecting the success of silage fermentation:

- water-soluble carbohydrate content of the forage
- buffering capacity of the forage
- moisture content of the forage
- predominant microorganisms
- fermentation speed

These factors are interrelated and can be affected by management of the silage making process.

### Water-soluble carbohydrate content

Microorganisms use water-soluble carbohydrates (WSC) as the main energy source for growth. The main sugars present in plants are fructose, glucose, sucrose and fructosans. There is only limited fermentation of other carbohydrates in plants such as starch, cellulose and hemicellulose.

Under some conditions, fermentation may be limited by a low WSC content of the forages. Under these conditions, the pH is not lowered enough to achieve safe preservation. Normally, a minimum of 6 to 12 per cent WSC is required for proper silage fermentation. It is therefore important to understand the factors that influence the WSC content of forages.

1. **Type of plant:** Legumes in particular contain low amounts of WSC (Table 1), and this is one reason why they are quite difficult to ensile. Grass species differ in the amount of sugars they contain, with timothy and orchard grass having lower amounts than some other grasses. Forage corn contains enough WSC to ensure successful ensiling. Barley forage contains adequate amounts for preservation at all stages prior to the ripe stage, so it must be harvested for silage before the hard dough stage.
2. **Stage of growth:** The WSC content of perennial grasses increases as the plants mature. In whole plant barley forage, WSC increases until about the milk stage.
3. **Growing conditions:** Plants contain much greater amounts of WSC when growing conditions have been cool with plenty of sunshine. Heavy rainfall during growth can reduce WSC up to 50 per cent.
4. **Management conditions:** WSC decreases during wilting. If wilting takes longer than normal, this reduction in sugars can have a very detrimental effect on the ensiling process.
5. **Drought:** Drought reduces the WSC content of forages.
6. **Daily variations:** Total WSC concentrations appear to increase in the morning and start to decrease in the afternoon.
7. **Fertilization:** High rates of nitrogen fertilizer can increase nitrate concentrations in forages. High nitrate levels are undesirable in the ensiling process. They are generally associated with lower levels of WSC. Some of the nitrates in forage are ultimately degraded to ammonia, which tends to raise the pH of the silage.
8. **Planting density:** WSC decreases if plant densities are high.

As can be seen from this list, management plays a vital role in WSC levels. Proper management in growing, staging and harvesting will ensure WSC levels will be high enough for good quality silage.

**TABLE 1**

**Water-soluble carbohydrate levels in dry matter of different crops***

| Forage | Water-soluble carbohydrates (%) |
|---|---|
| **Alfalfa** | |
| Vegetative | 9 |
| Early bloom | 7 |
| Full bloom | 7 |
| **Clovers** | |
| Cut 1 | 9 |
| Cut 2 | 5 |
| **Grasses** | **8-25** |
| Timothy | 10 |
| Orchard grass | 6 |
| Quack grass | 13 |
| Brome grass | 9 |
| Reed canary grass | 7 |
| Legume/grass mixtures (50:50) | 13 |
| **Corn silage** | |
| Early harvested | 31 |
| Medium | 14 |
| Late harvest | 8 |
| **Barley** | |
| Heading completed | 17 |
| Flowering | 18 |
| Milk stage | 32 |
| Soft dough stage | 24 |
| Ripe | 5 |
| **Sunflowers** | |
| Flowering | 19 |
| Seed stage | 19 |
| Dough stage | 12 |

*Examples of water-soluble carbohydrates in experimental forage.
Sources: Adapted from information in McDonald (1981) and Smith (1973)

## Buffering capacity

Buffering capacity is the degree to which forage material resists changes in pH. It influences the ease with which the forage can be ensiled. Forages with a high buffering capacity are highly resistant to a reduction in pH. Because low pH is necessary for good preservation, more acid must be produced to reduce the pH to desired levels. This is undesirable because more WSC must be used to produce the additional acid. It has been estimated that forages with a high buffering capacity require twice the amount of WSC to give good fermentation, compared with forages with a low buffering capacity.

The organic acids (malic, succinic, malonic and glyceric acid) in forages are mainly responsible for buffering capacity. In the ensiling process, these organic acids are degraded by bacteria and are replaced by acids with

stronger buffering properties. These replacement acids cause the buffering capacity of the forage to increase two- to fourfold. Plant proteins also increase the buffering capacity of silage.

Legumes are generally well buffered (Table 2), which means that more acid is required to lower the pH of the fermenting material. As a general rule, about 10 to 12 per cent WSC in legume dry matter will be sufficient for ensiling to occur. In comparison, grasses require a minimum of only 6 to 8 per cent, and beet pulp, which has a low buffering capacity, requires only 4 to 6 per cent WSC for good preservation. As can be seen from Table 1, legumes often contain less than the minimum amount of WSC, allowing an undesirable type of fermentation to occur.

**TABLE 2**
**Buffering capacities of forages**

| Crop | Buffering capacity* |
|---|---|
| Forage corn | 200 |
| Orchard grass | 300 |
| Ryegrass | 250 - 400 |
| Alfalfa | 400 - 600 |
| Clover | 500 - 600 |

* Buffering capacity is expressed as milliequivalents of NaOH required to change the pH from 4.0 to 6.0 in 1 kg of forage dry matter.
Sources: Adapted from McDonald (1973) and other sources.

Environmental conditions such as temperature, day length and moisture also influence the buffering capacity of forages. First-cut alfalfa has more buffering capacity than second- or third-cut alfalfa, whereas the reverse is true for some grasses.

## Moisture content

In general, the lower the moisture content in the crop, the higher will be the pH at which anaerobic stability is reached (Table 3). Organic acids are lost in the wilting process, and this reduces the buffering capacity of the plants, which improves the ensiling process. This factor is one of the reasons why field wilting is beneficial for crops that have low WSC contents and high buffering capacities.

**TABLE 3**
**Effects of wilting on composition of grass silage**

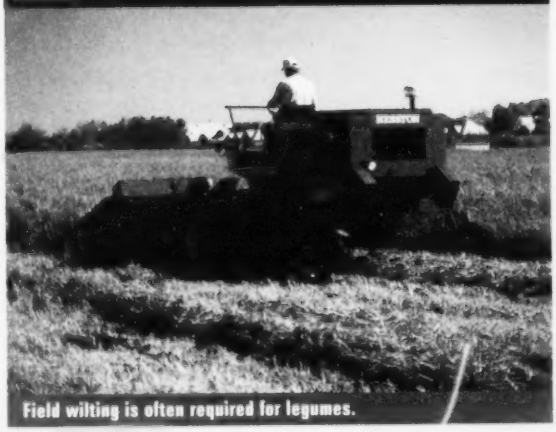
| Composition | Unwilted | Wilted |
|---|---|---|
| pH | 4.0 | 5.1 |
| Dry matter (%) | 15.8 | 35.0 |
| Lactic acid (%) | 16.5 | 3.4 |
| Acetic acid (% of dry matter) | 1.9 | 0.6 |
| Butyric acid (% of dry matter) | 0.5 | 0.1 |
| Ammonia nitrogen (% of total nitrogen) | 10.9 | 8.0 |
| Water-soluble carbohydrates | 1.1 | 18.5 |

Source: Morgan et al. (1980).

Wilting is also beneficial for ensiling because lactic acid bacteria are more tolerant to lower moisture concentrations than are the undesirable clostridial organisms. Very wet forage (greater than 70 per cent water) is therefore undesirable since clostridial growth may not be inhibited even when the pH drops to 4. Also with wet forages, the nutritional value and voluntary intakes of the silage produced are often low.

Wilting is usually restricted to perennial grasses and legume crops (Figure 1). Cereals usually have moisture levels suitable for rapid ensiling.

**FIGURE 1**



Field wilting is often required for legumes.

Several methods are commonly used to estimate moisture content of forages prior to being placed in the silo. Various types of moisture testers are commercially available. The hand or squeeze method of estimating moisture content in chopped forage is described in Table 20 and the microwave method is described in Table 21 in the *Harvesting* chapter.

### Predominant microorganisms

The most desirable fermentation occurs where lactic-acid-producing bacteria predominate. Although it is frequently assumed that fresh forage is adequately supplied with lactic-acid-producing bacteria, the numbers may be low under some circumstances. Many of the silage inoculants on the market are formulated to increase the numbers of these bacteria.

Following good silage making procedures will facilitate development of anaerobic conditions that aid in the rapid growth of lactobacilli in the silage.

### Fermentation speed

Rapid fermentation helps to maintain silage quality. Since the primary aim of storing forages as silage is to preserve the material with a minimum of nutrient loss, it is desirable to limit the nutrient consuming activity of aerobic microorganisms and to inhibit the breakdown of protein by clostridial microorganisms under anaerobic conditions.

The preceding discussion has covered the main factors influencing how rapidly fermentation will progress. Managing the ensiling process to ensure rapid fermentation helps to minimize nutrient loss.

## CHARACTERISTICS OF GOOD ENSILING PROCEDURES

### Exclusion of air

It is extremely important that air be excluded to optimize fermentation. There are several reasons for this:

- Plant respiration results in the loss of nutrients that would otherwise be available for the anaerobic bacteria to use for lactic acid production.
- The temperature of the ensiling forage increases when oxygen is present. This is generally undesirable since high temperatures lead to heat damage of the silage.
- Air in the silo delays the breakdown of the plant cells and the release of plant juices. This, in turn, delays the onset of rapid fermentation since the nutrients in the juices are not immediately available to the microorganisms.
- Exposure to excessive oxygen during silo filling encourages growth of fungi that cause greater instability and susceptibility to aerobic deterioration when silage is being fed.

All these factors tend to delay the development of the desirable lactic-acid-producing bacteria, encourage the proliferation of undesirable clostridial organisms, and promote protein breakdown.

The actual amount of atmospheric oxygen initially trapped in the forage is very small. Measurements have shown that if sealing is adequate, 99.5 per cent of the oxygen can be used up in 30 minutes by respiring plant tissues. This amount of combustion causes less than a 3°C temperature rise. However, considerable air can enter the forage if silage is not covered with plastic or sealed in some other manner. Slow silo filling, forage that is not chopped finely enough, and inadequate packing are other causes of excessive air in silage.

### Low temperature

When microbial growth occurs in silage, the temperature rises. In general, the greater the growth rate of microorganisms, the higher the temperature is. It is known that the rate of acidification is greater when silage temperatures are higher and that the onset of fermentation is earlier. As a result, people have incorrectly concluded that hot silage is good silage. In fact, higher temperatures encourage the growth of undesirable clostridial organisms that result in increased butyric acid and ammonia formation that is detrimental to silage quality. Temperatures in the 15 to 25°C range have been shown to allow growth of the desirable lactobacilli bacteria while inhibiting the growth of undesirable clostridial species. Silage temperatures should thus not exceed 30°C.

High temperatures also cause heat damage in silage. When the silage temperature exceeds 40°C in the presence of oxygen, a chemical reaction between plant WSC and protein occurs. This reaction produces brown products that give heat-damaged silage its characteristic brown color and a tobacco or caramelized odor. The protein that is bound in this 'browning reaction' is largely indigestible to the rumen microorganisms and to the animal. As can be seen in Table 4, the higher the silage temperature, the greater is the reduction in protein digestibility. Fresh forage protein typically has a true digestibility of approximately 90 per cent, regardless of the forage source. Excessive heating can reduce this digestibility to 30 per cent or less. It should also be noted that the longer the high temperature persists, the greater will be the damage to the forage.

**TABLE 4**

**Protein digestibility as affected by temperature and length of heating period**

| Heating period (days) | Protein digestibility (%) | | |
|---|---|---|---|
| | 43°C (110°F) | 57°C (135°F) | 71°C (160°F) |
| 0 | 69.7 | 69.7 | 69.7 |
| 3 | 68.7 | 65.8 | 60.2 |
| 9 | 68.4 | 64.4 | 50.0 |
| 18 | 65.2 | 58.6 | 35.8 |
| 30 | 65.4 | 49.0 | 30.1 |

Source: From Gallagher and Stevenson (1976).

Routine feed analysis does not detect heat damage. A special analysis to determine acid detergent insoluble nitrogen, more commonly referred to as ADIN, is required to determine the extent of heat damage to forages.

A limited amount of heat damage in silage may be beneficial in that heating produces protein that is resistant to digestion in the rumen but can be digested in the small intestine. This "bypass" or "escape" protein often results in improved performance of the animal, particularly those at high production levels. Controlled application of heat to produce bypass protein in some feed ingredients is used by the feed industry. However, this requires good control of temperature and duration of heating to be successful. In practice, there is little control of either in silage making; therefore, excessive heating in the silo should be avoided.

### Rapid acidification

Since it is ultimately the pH of the silage that stops the fermentation, pH is of great importance. The rate of acidification rather than the ultimate pH achieved is of the greatest importance, since rapid acidification reduces the risk of early growth of clostridial organisms. In direct-cut, high moisture crops, ensiling procedures should be such that rapid acidification is achieved. However with high dry matter crops, and if sterilants have been used, the rapid decrease in pH is not so important.

## CONTROLLING THE ENSILING PROCESS

### Moisture content

Controlling moisture content is the most important means of controlling the ensiling process. Wilting in the field is the practical way to obtain the correct moisture for ensiling. A desirable moisture level is 65 per cent, but slightly higher moistures may be desirable when long chop lengths are used, when packing is minimal or when the silage is not well sealed. Less moisture (40 to 50 per cent) is required in some oxygen-limiting silos. The recommended moisture content of forage stored in different types of structures is given in Table 5.

**TABLE 5**

**Silo type and recommended moisture levels**

| Silo type | Recommended moisture level (%) |
|---|---|
| Horizontal | 60 - 65 |
| Concrete tower | 60 - 65 |
| Oxygen-limiting | 40 - 50 |
| Silo bags (plastic tubes) | 55 - 60 |

At moisture contents greater than 65 per cent, seepage and loss of nutrients will occur in tower silos more than 30 feet high. Such high moisture levels will also encourage the growth of undesirable clostridial organisms.

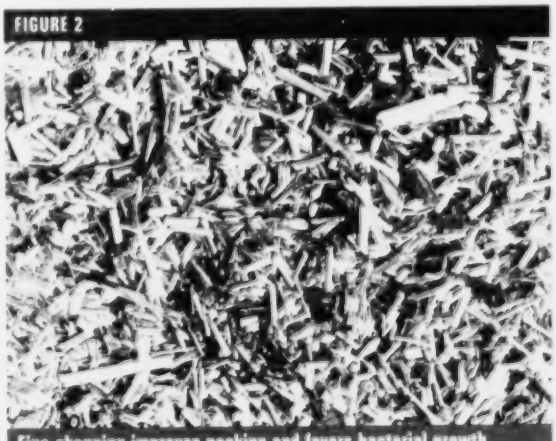
At moisture levels lower than 50 per cent, excessive heating is likely to occur unless an oxygen-limiting silo is used.

### Mechanical pretreatment

Chopping, cutting and bruising all improve the potential for making good silage (Figure 2). This result is due to cell breakage that favors bacterial growth and facilitates adequate packing for air exclusion.

Anaerobic conditions can be established quickly in cut forage. Thus, temperature rise may be limited to 25 per cent of that observed in forages that have not been chopped (such as round bale silage).

**FIGURE 2**



Fine chopping improves packing and favors bacterial growth.

More lactic acid is formed and less dry matter is lost when forage is chopped. Silage pH and ammonia content that result from protein degradation are reduced, and lactic acid concentrations are increased with progressively shorter chop lengths.

Where the length of cut has been reduced in silages, an increased voluntary consumption by cattle has been observed. For more information on silage chop length and consumption, see the *Feeding Value of Silages* chapter.

### Rapid filling, packing and sealing

Silos should be filled rapidly. The more time it takes to fill the silo, the greater the exposure of the silage to air will be.

Packing of silage is important to help exclude air from the silage in horizontal silos (Figure 3).

**FIGURE 3**

**Packing of silage helps to exclude air.**

Silage benefits from being sealed to exclude air. Generally, sealing benefits only the surface layer of the silage, but if the silage is not well packed, sealing is beneficial for the entire silage mass.

The silage making process can become anaerobic within 5 hours when the silage is sealed immediately after filling, whereas it can take up to 90 hours to become anaerobic when sealing is delayed for 48 hours. With alfalfa, it has been shown that a delay of as little as 12 hours in sealing the silo caused a butyric acid type of fermentation to occur instead of the more desirable lactic acid type of fermentation.

For more information on filling, packing and sealing, see the *Silos* chapter.

### Use of additives

The type and extent of fermentation that occurs in silage and the aerobic stability of the silage after it is removed from the silo can be controlled to some extent with silage additives. See the *Silage Additives* chapter for more information.

### Opening the silo

A second aerobic phase begins after the silo is opened and the silage is exposed to air. Aerobic microorganisms that have remained dormant in the absence of oxygen start to grow. This growth causes a rise in temperature of the silage. Normally, some mould appears at this time.

Silage may start to undergo aerobic deterioration within a few hours of exposure to air, but may also be stable for as long as a few days. Very high moisture silages with a high buffering capacity are most susceptible to aerobic deterioration because they are most likely to be contaminated by fungi. Also susceptible to aerobic deterioration are some silages in which fermentation has been limited with additives. Silages that are more resistant to aerobic deterioration at feeding are those in which the length of exposure to oxygen has been kept to a minimum by rapid filling and packing during silage making.

# Chapter 2: **Crops for Silage**

Both annual and perennial crops can make good silage. However, producers know that the feed value, digestibility and acceptability to livestock will vary depending on the crop and when it is cut. The three most common cereal crops used for silage are barley, oats and triticale. The major perennial crops include grasses and legumes.

Most annual and perennial crops can be harvested and stored as silage if they have sufficient water-soluble carbohydrates and adequate moisture content. Ensiling crops does not increase the feed value, but it may reduce the amount of feed value lost. After hay harvest, the feed value for each crop will decrease as the hay is dried down, baled and stored. If the crop is ensiled at 60 to 65 per cent moisture, there is less leaf loss, and if it is ensiled and covered quickly and properly, the crop shows little dry matter loss or spoilage. The longer the forage remains in the field to dry, the much greater the chance of weather damage due to rains.

The feeding value of the silage is related to the crop ensiled and the stage of maturity at which it is cut. The stage of maturity also affects the silage yield. As crops mature, silage quality decreases and yield increases. The loss of quality is due to an increase in fibre and a decrease in protein. However in some crops like barley, the increase in fibre is offset by the high digestibility of the grain forming in the heads.

While the feeding value of crops is not greatly affected by ensiling, palatability or acceptability to livestock may be improved. For example, sweet clover is more palatable as silage, and voluntary intake by livestock will be increased, resulting in improved animal performance. Ensiling also permits the use of weedy, hailed, droughted or frozen crops to be salvaged and used as livestock feed.

## ANNUAL CROPS

The majority of the silage in Western Canada is produced from annual crops. Cereal crops make up the largest acreage of silage crops with some corn grown in the southern areas where corn heat units are sufficient. Cropping practices for growing silage are generally similar to those for grain production.

Crop kind has a much greater influence on silage yield and quality than crop variety. Regional yield comparisons of commonly used annuals are listed in Table 6. Although there have been varietal improvements since this trial was conducted, the yield rankings between crops likely remain similar for the different soil and climatic areas. Yield and quality can vary from year to year due to rainfall and management.

**TABLE 6**
**Average dry matter forage yield indexes (% of oats) and crude protein for Alberta crops**

| Crop | Average crude protein (%) | Average dry matter forage yield indexes (% of oats) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Brown soil Brooks Bigstone | Brown soil Brooks (irrigated) | Dk. Brown soil Standard (irrigated) | Black soil Lacombe Olds-Cremona Westlock | Solonetzic soil Vegreville | Grey Wooded soil Bluffton Rocky Mtn. Hse Smoky Lake |
| Oats | 8.9 | 100 | 100 | 100 | 100 | 100 | 100 |
| Barley | 10.2 | 117 | 130 | 105 | 77 | 80 | 72 |
| Spring rye | 9.6 | 101 | 108 | 112 | 71 | 94 | 68 |
| Triticale | 9.7 | 102 | 114 | 111 | 81 | 96 | 75 |
| Field peas | 17.9 | 75 | 83 | 95 | 55 | 78 | 69 |
| Fababeans | 19.1 | 45 | 82 | 77 | 62 | 50 | 62 |
| Corn | 8.5 | 45 | 172 | 84 | 80 | 61 | 71 |
| Sunflowers | 11.6 | 109 | 163 | 137 | 88 | 136 | 91 |
| **Oat yield** | | | | | | | |
| lb/ac | | 4,340 | 7,920 | 7,720 | 8,948 | 5,295 | 6,281 |
| kg/ha | | 4,860 | 8,870 | 8,646 | 10,023 | 5,930 | 7,035 |

Source: Brooks Horticultural Station and Agriculture Canada Research Station, Lacombe, Annual Forage Trials, 1979 - 1983

**FIGURE 4**

**Barley is the most common annual silage crop. Spring triticale is good for silage and is ideal in a rotation. Oats is more tolerant of acid soils than barley.**

## Cereal silage

Cereal crops are the most versatile of the annual crops and have the ability to grow under the most diverse growing conditions. The three major cereals used for silage are barley, oats and triticale (Figure 4). Other cereals such as wheat, spring rye or winter cereals are sometimes used but generally only when there is a feed shortage or as a salvage crop.

Cereals are high in water-soluble carbohydrates and low in buffering capacity, which makes them very easy to ensile (see *Ensiling Process* chapter). Digestibility varies by crop species, stage of maturity at harvest, crop type and, to some extent, variety (Table 7). As cereal crops mature, fibre content increases and protein content decreases. Cereal crops are generally harvested at or before the mid-dough stage when the crops are at 60 to 65 per cent moisture. This produces the maximum crop yield at a moisture content that allows for good fermentation of the silage.

**TABLE 7**

**Forage yield and quality of crops, Lacombe (1993 -1995)[1]**

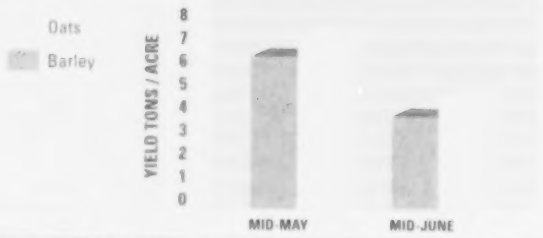
| Crops | Yield (t/ha) | Crude protein (%) | IVDOM[2] | NDF[2] | ADF[2] |
|---|---|---|---|---|---|
| Semi-dwarf barley | 11.1 | 11.0 | 68 | 49 | 27 |
| Standard type barley | 11.5 | 9.5 | 60 | 59 | 34 |
| Oats | 13.1 | 9.0 | 62 | 55 | 34 |
| Triticale | 14.4 | 9.7 | 66 | 48 | 29 |

[1] Crops grown at Lacombe and harvested at early dough stage.
[2] IVDOM is in vitro digestible organic matter. NDF is neutral detergent fibre. ADF is acid detergent fibre.

Farm operations with large acreages of cereals for silage grow different crops or varieties with varying maturity dates to enlarge the harvest window. Although delayed seeding will also widen the harvest window, it can result in a significant loss in silage yield (Figure 5).

**FIGURE 5**

**Time of seeding vs. yield for barley and oats at Lacombe**




Source: Unpublished data, S. Kibite, Agriculture and Agri-Food Canada, Lacombe Research Centre, 2001

If a higher protein silage is required for feeding, the crops can be cut at an earlier stage of maturity, fertilized more heavily with nitrogen or manure, or grown in mixtures with higher protein crops such as field peas, spring-seeded winter cereals or ryegrasses. The tradeoffs of these options are generally higher production costs and/or reduced yields. It may be less expensive to supplement the diets with protein.

Many silage producers have been growing the same crops and the same varieties on the same fields for many years. This has resulted in reduced yields due to a buildup of cereal diseases on the crop residue and in the soil. Reduced yields of up to 20 per cent have been found in some barley silage fields where the producers have not been using a good crop rotation to reduce the buildup of

disease in their crops. Some research indicates that there may be some value in rotating varieties of a cereal such as barley to reduce the disease infestation.

## Barley

Barley is adapted to most soil types provided rainfall is adequate. It responds to high levels of fertility and good moisture. Since barley is an early maturing crop with some drought tolerance, it has a low water requirement. In irrigated areas, maximum silage yields can be obtained with a total of 375 to 450 mm (15 to 16 in) of water. For example, if 200 mm (8 in) of water are available from soil storage and rainfall, then about 150 to 175 mm (6 to 7 in) of irrigation water are needed. Moisture stress at the time of tiller initiation and development will reduce yield. Water requirements are the highest from the shot blade stage to the time of kernel formation. High soil moisture during the jointing and boot stages promotes vegetative growth, but also increases lodging.

Barley is more tolerant of saline soils than other cereals. Barley yields 50 per cent of normal on a soil with an electrical conductivity of about 8 to 9 mmhos/cm. In comparison, wheat produces 50 per cent of normal yield at about 7 mmhos/cm.

Barley is less tolerant of acid soils than oats.

Barley can be seeded from early May until early June and still make silage. However, delayed or late seeding will affect yields (Figure 5). Seeding in mid to late May produces the best yields. Seeding rates should be 85 to 140 kg/ha (75 to 125 lb/ac). As for grain, high rates of fertility, especially nitrogen, are required for high yields. The higher rates of seed and nitrogen should be used in areas of high rainfall or irrigation. Variety selection is important, as lodging may be a problem when barley is grown under high fertility and high moisture conditions.

There are two main types of barley: standard or feed types (as opposed to malting varieties) and semi-dwarf types. The standard types are all long stemmed varieties. They vary in plant height, have 2 or 6 rows of seed on the head, differ in maturity, lodging resistance and most importantly, resistance to diseases. Standard type barleys are more suited to dryland silage production. The taller standard types tend to yield more under dryland production than semi-dwarfs.

The semi-dwarfs are generally 6-row feed varieties, but some are 2-row. They vary in days to maturity, disease resistance and, to some degree, plant height. They all have very good to excellent lodging resistance, which makes them ideal for growing in areas of high moisture or irrigation and areas of high fertility. In these areas, the semi-dwarfs will yield similar to or greater than the standard types and generally will not lodge.

Both barley types have rough and smooth awned varieties. Rough awns, if harvested when the plant is too dry, may cause sores or lesions in the animal's mouth. The awns become brittle and sharp and can become lodged in the lining of the mouth or throat.

Plant breeding institutions are beginning to breed forage barley types. These varieties generally are hooded types (no awns) or they have smooth awns. They are being developed to increase forage quality. Before choosing one of these varieties, determine if the yield, quality and disease resistance are comparable to the other varieties. Hulless barleys are also being developed for grain for livestock feeds. There is a misconception that since the grain is higher in quality, the silage will be as well. When used for silage, the hulls are included, which negates the value of the hulless attribute.

When choosing barley varieties for silage, the rule of thumb is *varieties that produce the highest seed yields will generally produce the highest silage yields*. Figures 6, 7 and 8 indicate the ratios of the stem, leaves and grain in two barley types, an oat and a triticale at Lacombe. In barley, the grain content in the silage varied between 30 and 55 per cent of the total yield of the silage, depending on the growing conditions. The average grain component of the silage was about 45 per cent of the total yield in both barley types. The stem made up a higher percentage of the standard type than the semi-dwarf type. The standard type averaged 35 per cent stem and the semi-dwarf averaged 30 per cent stem over three years. There was year-to-year variation in the proportion of stem in both varieties. The difference in per cent leaf between the barley types varied by 1 to 3 per cent, which is not enough to make a significant difference in the quality of the silage.

**FIGURE 6**

**Crop components - per cent leaf for barley, oats and triticale**

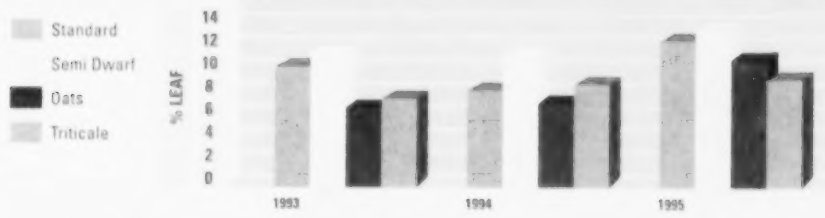



**FIGURE 7**

**Crop components - per cent stem for barely, oats and triticale**

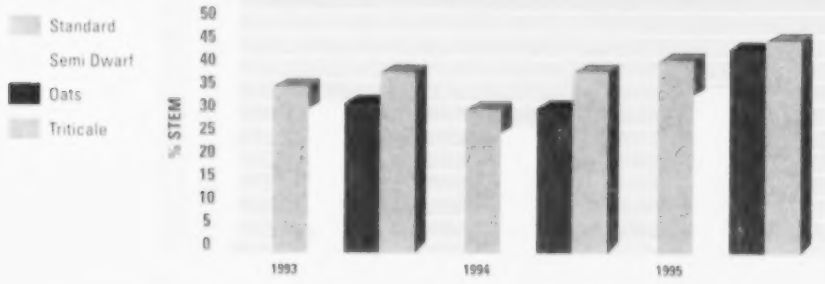
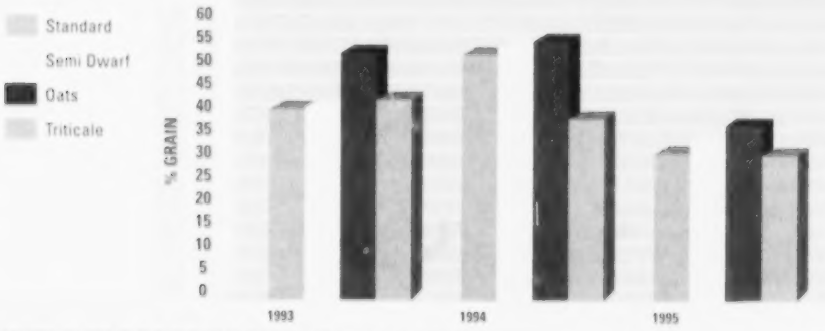



**FIGURE 8**

**Crop components - per cent grain for barley, oats and triticale**




Source: Unpublished data from V. Baron, Lacombe Research Centre, Agriculture and Agri-Food Canada

**NOTES** Notes for Figures 6, 7 and 8

- Balance of the total yield was made up by awns.
- Barley was sampled at the dough stage.

Figures 6, 7 and 8 indicate that the year-to-year variation in leaf, stem and grain is greater than the variation between barley types. Oats and triticale had similar ratios, with the triticale generally having a higher per cent stem. In comparison, barley had a higher per cent leaf content than the other crops.

There has not been enough research to determine differences in quality (digestibility, protein, fibre levels) among all the barley varieties. However, semi-dwarf types tend to have higher feeding value than standard types. The lower ratio of stem to grain in the semi-dwarf barleys has been shown to produce silage with lower fibre levels and higher digestibility than the longer-strawed standard varieties (Table 7). Of the cereal crops, barley is the highest quality crop when cut at the same stage of maturity, although new triticale and oat varieties have been developed with improved quality.

For ensiling with horizontal silos, harvest should be completed by the time the standing crop drops to 65 per cent moisture since some moisture is lost during harvest. In central Alberta, the moisture content of standing barley drops by about 1 per cent per day. The 65 per cent moisture level occurs about three weeks after heading, that is, at the early dough stage (Figure 10).

**FIGURE 9**

**Per cent of total yield as crop matures, for oats, barley and triticale**

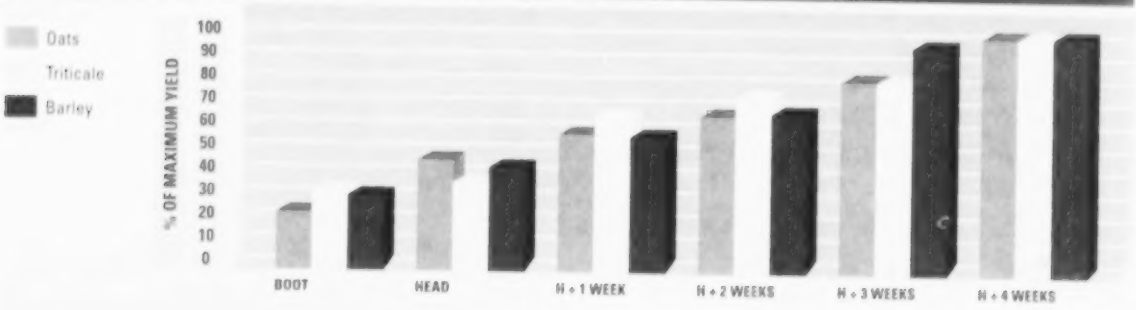



**FIGURE 10**

**Silage per cent moisture as crop matures, for oats, barley and triticale**

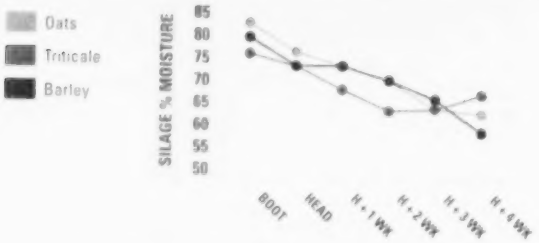
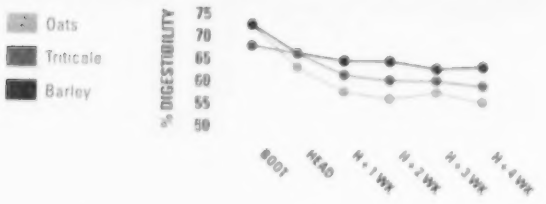



**FIGURE 11**

**Silage digestibility (in vitro digestibility) as crop matures, for oats, triticale and barley**




**NOTES** Notes for Figures 9, 10, 11 and Table 8

- Oats and triticale reached the heading stage in 69 days, barley in 63 days.
- Maturity was as follows:
  - Oats – Heading plus 2 weeks was medium milk, heading plus 3 weeks was late milk and heading plus 4 weeks was early dough stage.
  - Triticale – Heading plus 3 weeks was early milk and heading plus 4 weeks was watery dough stage.
  - Barley – Heading plus 2 weeks was watery dough, heading plus 3 weeks was early dough and heading plus 4 weeks was soft dough stage.
- Cereals are considered to be headed when 50% of the heads on the main tiller are above the boot.
- "H+1WK" is heading stage plus one week, "H+2WK" is heading stage plus two weeks and so on.

Per cent moisture, total yield, relative yield and per cent digestibility of oats, triticale and barley on Black soil are shown in Figures 9, 10 and 11 and in Table 8. These figures also show the yield, quality and moisture changes of the crops as they mature.

Barley has a higher per cent digestibility than other cereals except wheat. Again, Lacombe data showed barley had 63 per cent digestibility at three weeks past heading compared with oats at 56 per cent and triticale at 60 per cent (Figure 11). For livestock rations, increased digestibility is associated with higher levels of dry matter intake when the percentage of digestible dry matter is below 70 per cent.

Standard barley also has similar crude protein levels as other cereals at a similar stage of maturity (Table 7). Semi-dwarf barley had the highest per cent protein. Higher protein contents can also be obtained by harvesting earlier, although yields will be reduced. For example, research at Brooks (AHRC 1984, p. 53) indicated the highest protein content is attained from the boot-to-head-emerged stage, but yields are approximately one-half those at the dough stage.

**TABLE 8**

**Total silage yield of cereal crops, based on maturity**

| Maturity | Yield (kg/ha) | | |
|---|---|---|---|
| | Oats | Triticale | Barley |
| Boot | 1,680 | 1,809 | 2,093 |
| Head | 3,149 | 2,260 | 2,980 |
| Heading + 1 week | 4,196 | 3,770 | 4,000 |
| Heading + 2 weeks | 4,980 | 4,578 | 5,160 |
| Heading + 3 weeks | 6,073 | 6,040 | 6,776 |
| Heading + 4 weeks | 7,113 | 5,920 | 7,070 |

## Oats

Oats yield the highest total dry matter and total energy of all cereals in the Grey Wooded soil areas. They yield more total dry matter, but not necessarily more digestible material per hectare (or acre) than other cereals on Black soils (Table 6). Oats are recommended for silage production on Dark Brown soils, but are lower yielding than some other cereals.

Compared with other cereals, oats are more tolerant of acid soils and of excessive soil moisture, but are less tolerant of salinity than barley or wheat. They are also intolerant of manganese deficiency, which is associated with a physiological disease known as grey speck. Manganese deficiency is often associated with low lying, high organic matter soils (i.e., cold soils) and sandy soils.

Oat varieties most suited to fodder production may be different from those that give the greatest grain yield. There are also differences in lodging resistance and days to maturity among varieties. Lodging is more frequent when oats are grown with high rates of nitrogen fertilizer and when soil moisture levels are high.

Plant breeding institutions are developing forage and dual purpose types of oats. These varieties tend to have a high forage yield and increased digestibility. The old forage oat Foothills had reasonably good quality but very poor lodging resistance. The new forage oats have a feeding quality similar to Foothills along with better lodging resistance.

Recommended planting rates for oats for silage production range from 73 to 129 kg/ha (65 to 115 lb/ac). The higher planting rates result in less tillering, finer stems and decreased plant height. The lower planting rates are advantageous in drier areas. The planting rate does not have a significant effect on silage quality. The optimum time to plant oats for silage production is about mid-May in northern and central regions, and late May in the south. Planting later will result in decreased yields (Figure 5).

Lacombe data indicate that the moisture content of standing oats dropped to 65 per cent at about three weeks after heading, that is, at the late milk stage (Figure 10). At the late milk stage, oats had produced about 85 per cent of maximum total yield (Figure 9 and Table 8). Although maximum total yield was reached at the early dough stage, delaying harvest until this time resulted in moisture levels of 60 per cent. Harvest should

**FIGURE 12**

**Energy value of the major plant components at progressive stages of development of oats (pooled values for three varieties)**

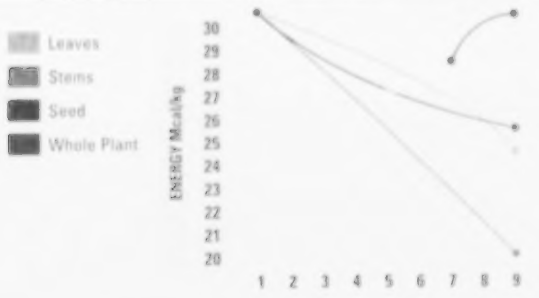
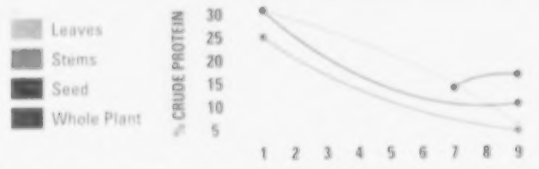



**FIGURE 13**

**Crude protein of major plant components at progressive stages of oat development (pooled values for three cultivars)**




Source: Agriculture Canada Research Station, Swift Current, 1973

**NOTES** Notes for Figures 12 and 13

**Cutting stages were as follows:**
1 and 2 - leaf, 3 - boot, 4 - heading, 5 - early bloom, 6 - late bloom, 7 - milk, 8 - dough and 9 - ripe

begin prior to this time to avoid the silage becoming too dry, which could result in greater storage losses.

Energy levels per pound (or kilogram) are high in early growth stages, but they gradually decline with maturity and level off when the kernels begin to develop (Figure 12). The per cent digestibility of oats at normal ensiling stages is slightly lower than other cereals (Figure 11). When comparing total dry matter yields of oats to other cereals, the lower digestibility of oats should be considered.

The protein content of oats is lower than that of other cereals (Table 7). The proportion of crude protein does not usually drop below about 8 per cent since the developing seed contributes to protein content from the milk stage onwards (Figure 13). Total amount of protein per hectare (or acre) continues to increase until the dough stage.

In some areas, cereal mixtures are used to increase silage yield and quality. A common mix is barley and oats. Mixtures may increase both yield and quality, but never is the yield or quality higher than when the crops are grown alone. If oats yield higher than barley and are grown in a mixture, the result is generally a yield less than oats and quality less than barley; however, the yield may be higher than barley grown alone and quality greater than oats alone.

### Spring triticale

Triticale is a relatively new cereal crop for forage use. Triticale yields are similar to barley or oats yields in most areas of the province. Silage yields vary depending on growing conditions, area of production and variety. Triticale produces very well under dryland conditions. In the Black soil areas, the newer triticale varieties have yielded higher than barley or oats, and the strong straw reduces the potential for lodging. In the Grey Wooded areas, oats generally out-yield both triticale and barley.

Triticale should be planted in early to mid-May. The seed size of triticale varies considerably depending on the variety. It should be seeded at about 95 to 146 kg/ha (85 to 130 lb/ac) for silage production. The strong straw of the triticale allows it to withstand high levels of nitrogen fertility from fertilizers or livestock manure.

Along with superior lodging resistance, one of the main advantages of triticale is late maturity. The moisture content of triticale at Lacombe was still 65 per cent at four weeks after heading, which is the watery dough stage (Figure 10). At the watery dough stage, total yield of triticale was almost as high as oats at three weeks past heading, when oats harvest should be completed (Table 8), and digestibility was intermediate between oats and barley (Figure 11). The protein content of triticale is intermediate between oats and barley (Table 7).

The late maturity of triticale permits producers with large silage acreages to extend harvest over a longer period and maintain good silage quality by avoiding the ensiling of over-ripe cereals. Triticale is difficult to harvest and requires more horsepower to operate the harvester than other cereal crops.

Feed intake has been reported as a problem in some cases, especially when triticale is fed to calves. Other feeds should be available to feed or blend with the triticale if the problem arises. The intake problem is not consistent and generally is not a concern. Research has not determined the cause of the problem.

### Winter triticale

Winter triticale is a winter cereal that must be seeded in the fall and be exposed to freezing temperatures to produce seed. This vernalization period allows the formation of seed heads that add to the silage yields.

Winter triticale is adapted to the Brown, Dark Brown and Black soil areas of Alberta. It is not as winter hardy as fall rye but is hardier than winter wheat. Depending on seed size, winter triticale should be seeded at the rate of 95 to 146 kg/ha (85 to 130 lb/ac) between mid-August and mid-September to ensure good establishment and sufficient winter hardiness.

The agronomics of growing winter triticale are similar to growing spring triticale. Winter triticale has lower forage quality than the spring type. Harvest of winter triticale will generally be two to three weeks earlier than spring triticale. This spreads out the harvest for producers with large acreages of silage.

### Spring wheat

Although not commonly used for silage, spring wheat is satisfactory for this purpose. It yields well in the Brown soil zone, especially under irrigation. Wheat is intermediate between oats and barley for tolerance to salinity and acidity. Wheat tolerates a salinity level of about 7 mmhos/cm as measured by electrical conductivity (compared with 8 mmhos/cm for barley) and a pH of 5.5 (compared with 4.5 for oats).

Utility wheat varieties are most often used for silage, but hard red spring wheat varieties are better adapted to severe drought. Soft white wheat has yielded well for silage under irrigation in southern Alberta.

Wheat should be planted from mid to late May at about 84 to 124 kg/ha (75 to 110 lb/ac) when grown for silage. Wheat should be harvested in the early dough stage for most silage uses.

Nutrient quality is satisfactory compared to other cereals. For example, at Brooks under irrigation, wheat varieties had 12.2 per cent protein in four years of tests compared to barley at 11.8 per cent, oats at 11.7 per cent, and triticale at 11.6 per cent. In the same tests, wheat

varieties had 29.6 per cent acid detergent fibre compared with barley at 26.5 per cent, oats at 31.5 per cent and triticale at 30.1 per cent.

### Winter wheat

Fall-seeded winter wheat has a growth habit similar to that of spring-seeded wheat. However, winter wheat yields are somewhat lower and more variable than yields for other cereals because of winterkill, making it less reliable as a silage crop. However, its early maturity does broaden the silage harvesting window.

Spring-seeded winter wheat gives low silage yields and requires at least two cuttings. Spring-seeded winter wheat will not head out because it must go through a vernalization period to produce seed heads. Mixing winter wheat with another cereal may have benefits, provided the regrowth is used as pasture. Brooks data indicate barley plus winter wheat yielded 94 per cent as much silage as barley alone, but it produced two simulated pasture clippings that gave a total of 20 per cent more yield (AHRC 1984, Table 64).

### Spring rye

Spring rye is adapted to the Brown and Dark Brown soil areas, especially under irrigation. In these areas, yields are similar to those of other cereals. Spring rye also does well in the Black soils of southwestern Alberta. Crop height is somewhat greater, which may be an advantage under dryland production in dry seasons. Spring rye should be planted from mid to late May at 95 to 157 kg/ha (85 to 140 lb/ac) when grown for silage.

Silage quality is comparable with that of other cereals. At Brooks, under irrigation, spring rye had 10.6 per cent protein and 30.1 per cent acid detergent fibre over four test years.

### Fall rye

Fall rye yields well in all soil zones. It is very winter hardy and has the advantage of using good spring moisture to promote early growth. This quality is especially useful on sandy soils with low water holding capabilities and in areas of lower rainfall. Fall rye is capable of producing an early crop of silage and lengthening the silage making season.

Fall rye should be seeded between August 1 and September 15. The more northerly the growing area, the earlier it should be seeded. A seeding rate of 90 to 124 kg/ha (80 to 110 lb/ac) provides a sufficient number of plants for a good yield. Fall rye tillers profusely if adequate soil moisture and nutrients are present.

For maximum silage yields, it is recommended that fall rye not be grazed in the fall or spring.

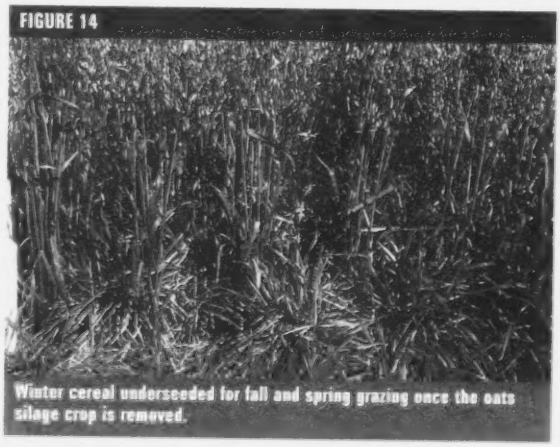
Fall rye for silage is ready two to four weeks earlier than most cereal silages. It should be cut at the milk to early dough stage. If allowed to mature too long, ergot bodies may form. Ergot bodies may cause abortions in livestock.

The quality of fall rye silage is comparable to that of other cereal crop silage. Total dry matter yields of fall rye are generally lower than those of oats, but in some cases will out-yield barley.

### Cereal silage/pasture intercrop

Intercropping is a cropping system that uses two crops grown together, either for the same purpose or different purposes (Figure 14). Spring cereals (barley, oats and triticale) and winter cereals (fall rye, winter triticale and winter wheat) work well together in an intercrop system and may be used for summer and fall pasture or for silage/fall pasture.

**FIGURE 14**



Winter cereal underseeded for fall and spring grazing once the oats silage crop is removed.

A silage/pasture intercrop system, utilizing the spring cereal as a silage crop and the winter cereal as a pasture crop after the silage has been removed, is a system that provides a higher quality silage crop along with a high quality fall pasture that is productive well into the fall.

The winter cereals and spring cereals should be seeded simultaneously at three-quarters of the normal rates of each crop, depending on the moisture conditions in the

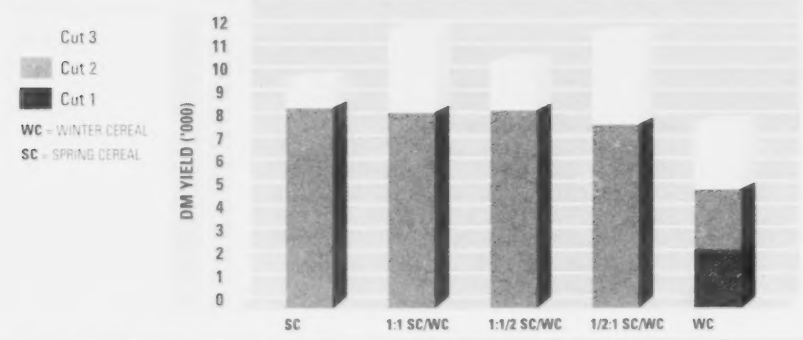
production area (Table 9). This seeding rate should produce an adequate balance between silage and pasture production. Research at Brooks (Figure 15) indicated that increasing the proportion of the spring cereal in the seeding mixture increased silage production, whereas increasing the proportion of the winter cereal increased pasture production. The producer has some flexibility in managing for the component that is most important in the operation by adjusting the seeding rate ratios.

**TABLE 9**
**Intercrop seeding rates based on moisture conditions**

| Crop | Seeding rates (lb/ac) | |
|---|---|---|
| | Dry conditions | Wet conditions |
| Winter cereals | 60 | 80 |
| Barley | 55 | 75 |
| Oats | 45 | 60 |

Source: Aasen and Baron (1993).

**FIGURE 15**
**Seeding ratios vs. dry matter yield in spring cereal/winter cereal intercrop (lb/acre)**




Source: H. Najda, Alberta Agriculture, Food and Rural Development and V. Baron, Agriculture and Agri-Food Canada, 1986-89.

This system should be fertilized as a normal silage crop and top-dressed with nitrogen after silaging to stimulate the winter cereal growth for pasture. The amount applied will depend on soil tests taken after the removal of the silage crop and the soil moisture levels.

In the silage/pasture system, it is necessary to maintain a healthy stand of winter cereal. Lodging of the spring cereal crop will kill the underseeded winter cereals. The silage crop should be harvested early (two to three weeks after heading) to allow the winter cereal sufficient time to regrow for good fall pasture. The crop should be cut short to take advantage of the quality and quantity of winter cereal in the mixture.

Results from Lacombe and Brooks (Table 10) indicate that silage quality may be improved by the addition of the winter cereal. Protein has been shown to increase

**TABLE 10**
**Quality of intercropped silage**

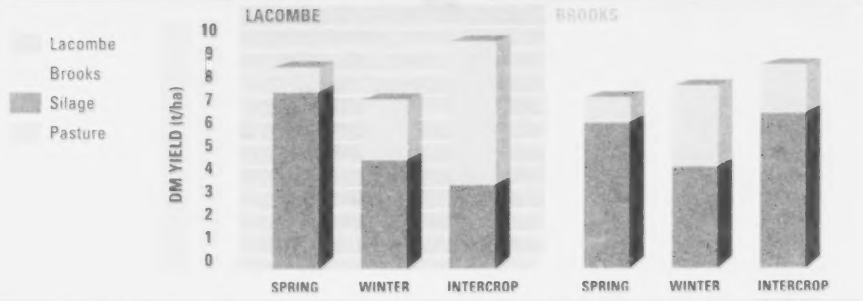
| Crop | Protein (%) | Digestibility (%) |
|---|---|---|
| Oats | 10.2 | 58.0 |
| Barley | 10.6 | 64.3 |
| Winter cereal | 19.5 | 74.7 |
| Oats/winter cereal | 14.0 | 62.8 |
| Barley/winter cereal | 12.8 | 66.8 |

Source: V. Baron, D. Salmon, H. Najda and A. de St. Remy, Lacombe, Agriculture and Agri-Food Canada, and Alberta Agriculture, Food and Rural Development, Brooks.

up to 3.8 per cent and digestibility up to 4.8 per cent, with the addition of a winter cereal to the silage crop. Silage yields may be reduced by 10 to 15 per cent in some areas, depending on the amount of moisture received during the growing season. Drier areas may expect lower yields while higher rainfall and irrigated areas may not have any yield reduction.

Figure 16 indicates the initial growth and regrowth when growing single species and intercrop spring and winter cereals. The initial production of the spring cereals seeded alone for silage may be higher than the intercrop mixture, but the

**FIGURE 16**
**Silage/pasture yields in a spring cereal/winter cereal intercrop**




Source: V. Baron et al., Agriculture and Agri-Food Canada

regrowth with spring cereals alone is much less than the regrowth with the intercrop mixture. Silage and pasture yields combined using an intercrop system produce more forage per hectare (or acre) and compensate for the potentially reduced silage yields.

Once the winter cereal regrowth has reached 15 to 20 cm (6 to 8 in), the crop may be grazed. Winter cereals have quick regrowth, depending on the moisture, fertility and daytime temperatures in September, October and November. Winter cereals have the ability to remain green, viable and productive, even after being subjected to gradual decreases in temperature down to -20°C. Fall rye and winter triticale are the most productive winter cereals in an intercrop system. They are more productive in the fall than winter wheat. (For more information see *Winter Cereals for Pasture*, Alberta Agriculture, Food and Rural Development Agdex 133/20-1.)

## Silage corn

Corn is frequently grown for silage production in irrigated areas receiving adequate heat units; a minimum of 2100 corn heat units for six out of 10 seasons is required for consistently high yields. Corn is the highest yielding crop for silage under irrigation in areas where heat unit accumulation is not limiting (Table 6). The growth and development of corn increase rapidly from an air temperature of 10°C up to 30°C (50°F to 85°F). Under good growing conditions, the production of a corn plant continues at a rapid rate until midway through the grain filling stage (Figure 17).

**FIGURE 18**

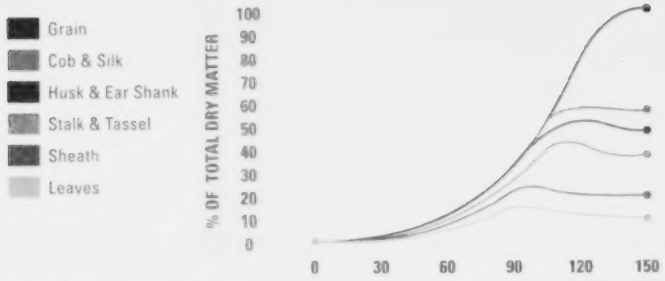
Harvesting corn requires specialized equipment.

Despite its high yield potential, the economics of corn production should be assessed very carefully since corn requires higher input costs than small grain silage. Seed, herbicide, planting and harvesting equipment (Figure 18) requirements are different than for small grain silage production.

Attempting to produce corn silage in areas that are, on average, cooler than recommended is likely to result in lower production compared with crops suited to cooler conditions (Table 11). In cooler areas, the crop may have to be harvested when it is immature for silage and before it has reached maximum yield. In short season areas, such as Alberta, silage yield will likely be proportional to accumulated corn heat units; warmer locations and varieties adapted to them will have the highest yields (Table 11).

**FIGURE 17**

**Relationship between distribution of dry matter in a corn plant and days from planting in Alberta**




Source: Alberta Corn Commitee (1982)

**TABLE 11**

**Silage dry matter yield, per cent dry matter (DM) and per cent ear of whole plant for corn, triticale, barley and oats at three Alberta locations**

| Crop | Bow Island[1] | | | Brooks[1] | | | Lacombe | | |
|---|---|---|---|---|---|---|---|---|---|
| | Yield (t/ha) | DM (%) | Ear (%) | Yield (t/ha) | DM (%) | Ear (%) | Yield (t/ha) | DM (%) | Ear (%) |
| Corn (4 varieties) | 14.2 | 38 | 53 | 12.8 | 37 | 50 | 9.1 | 24 | 27 |
| Triticale (1 variety) | 3.8 | 34 | — | 7.5 | 36 | — | 10.2 | 31 | — |
| Barley (2 semi-dwarf varieties) | 5.1 | 37 | — | 8.3 | 35 | — | 7.7 | 27 | — |
| Oat (1 variety) | 4.8 | 29 | — | 7.0 | 26 | — | 12.0 | 23 | — |

[1] Brooks and Bow Island locations were irrigated.
[2] Corn hybrids ranged from 2000 to 2400 corn heat unit rating. Corn heat units from planting until harvest were 2419, 2362 and 1854 for Bow Island, Brooks and Lacombe.

In southern Alberta, the Alberta Corn Committee tests varieties for relative silage potential at several locations and publishes the results in a *Hybrid Performance Trials* brochure each year. Growers should check this list before choosing a variety.

Silage corn is normally harvested beginning at 70 per cent moisture, that is, prior to grain maturity. Since silage corn only needs to reach this stage by the first fall frost, a later variety than recommended for grain corn may be desirable, because later varieties usually yield more silage dry matter than earlier ones. In the corn growing areas of Ontario, the margin between 70 per cent moisture and grain maturity is about 200 corn heat units. Varieties for silage can be selected by determining the corn heat units for the area where corn is to be grown, and then choosing a variety that requires up to 200 heat units more than are available in this area. However, in cool, short season areas, such as Alberta, this margin may not be as large as in Ontario. Experience will determine which varieties usually give the highest yield of the correct maturity before frost.

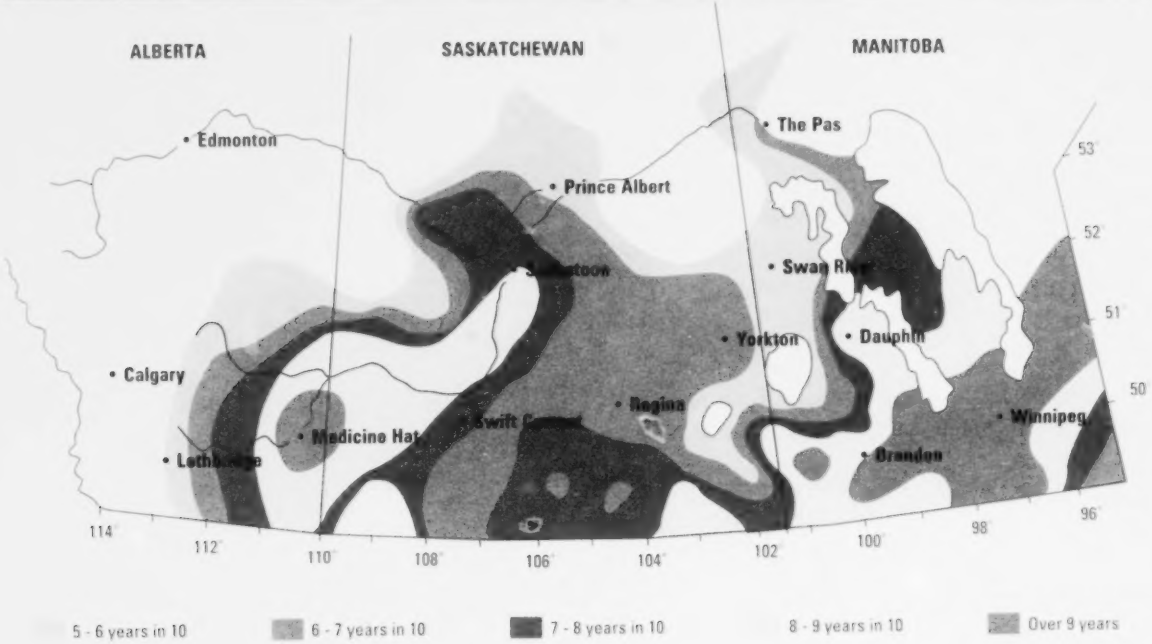
It should be noted that a hard frost will lodge a crop with more than 75 per cent moisture. Also, a high moisture crop must be ensiled as soon as possible after a killing frost to avoid losing nutrient value.

The corn heat unit maps (Figures 19 and 20) can be used as a general guide as to where silage corn can be produced. The slope of the land, elevation and soil type also affect the amount of heat a specific field receives. It is recommended that silage corn be grown in areas receiving an average of 2100 heat units or more.

The corn heat unit (CHU) system rates corn hybrids and geographic locations on a common basis. Corn development varies with temperature, so a relationship between temperature and development is used as a basis for the ratings.

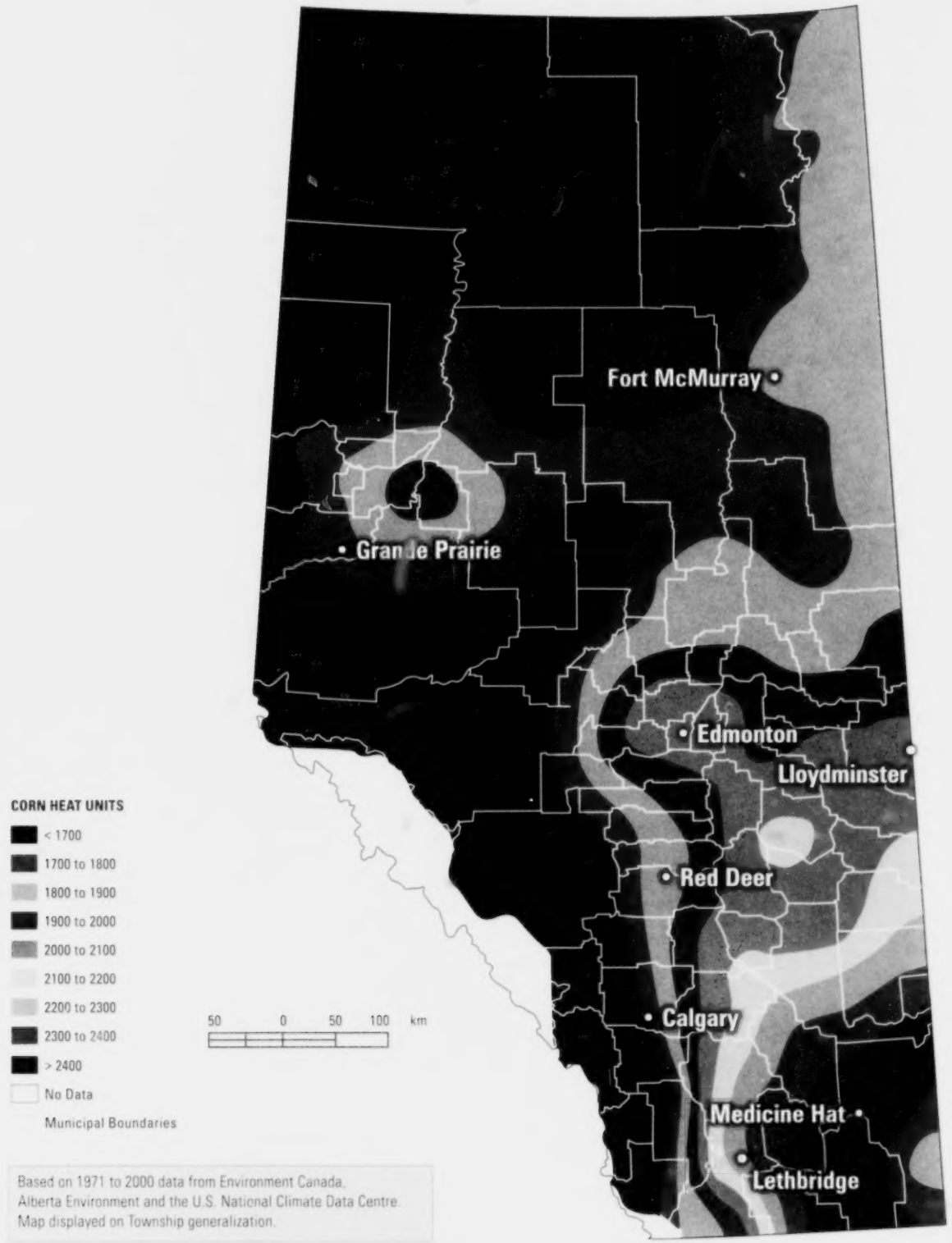
The CHU system treats the daytime temperature separately from the nighttime temperature. The daytime relationship uses 10°C as the base, below which no development occurs, and 30°C as the optimum temperature. The nighttime relationship uses 4°C as the

**FIGURE 20**
**Probability of receiving 2100 corn heat units**



ALBERTA
SASKATCHEWAN
MANITOBA
• Edmonton
• Prince Albert
• Saskatoon
• Swan River
• Yorkton
• Dauphin
• Calgary
• Regina
• Swift Current
• Medicine Hat
• Lethbridge
• Brandon
• Winnipeg

**FIGURE 19**
**Average number of corn heat units received.**



base temperature with no optimum. The contribution to CHU by daytime (maximum) temperature is determined from the equation:

$$Y = 3.33(T_{max} - 10) - 0.084(T_{max} - 10)^2$$

where Y is the CHU value for the daily maximum Celsius temperature, $T_{max}$.

Values for nighttime (minimum) temperatures are determined from the following equation:

$$X = 1.8(T_{min} - 4.4)$$

Where X is the CHU value for the daily minimum Celsius temperature, $T_{min}$.

The two daily values, X and Y, are averaged to provide a CHU rating for each day in the corn growing season. The daily CHU values are summed over the growing season to give a seasonal rating for the site. For more information, see the latest edition of *Corn Heat Units in the Prairies* or the Alberta Corn Committee's *Hybrid Performance Trials*.

Corn requires well drained soils for best production. Fine textured soils require good internal and surface drainage for satisfactory production. Corn is sensitive to salinity; it will have about a 50 per cent yield reduction on soils having an electrical conductivity of 4.5 to 5 mmhos/cm in the top 30-cm (12-in) layer of soil.

As with most crops, a shallow seedbed should be prepared in the spring to maintain moisture and help keep the soil firm. Corn for silage should be planted in late April to the first week in May in southern Alberta. Soil temperature for germination must be at least 10°C. Early cultivation, avoiding excess crop residue on the soil surface, and good soil moisture levels help to make early planting possible.

For silage production on irrigated land, corn should be precision seeded at 75,000 plants per ha (30,000 plants per acre), that is, 1 seed per 15 cm (6 in) of row with a 75-cm (30-in) row spacing, assuming 85 per cent survival. It may be necessary to plant corn at lower densities for dryland production in southern Alberta. However, as breeders develop earlier corn hybrids, mature corn plants often become smaller in stature. To be competitive in dry matter production with other crops, corn populations may have to increase above 75,000 per ha (30,000 plants per acre). In short-season areas of the U.S., corn silage yields increased up to 100,000 per ha (40,000 plants per acre).

A narrower row spacing of 38 cm (15 in) compared to 75 cm (30 in) has also increased silage yield, but at a much lower rate (4 to 9 per cent) compared to increasing plant population per se. Harvesting corn silage in narrow row spacing requires a specialized and flexible corn head for silage harvesting equipment.

Higher corn populations may increase silage yields where corn is adapted, but in dry years, the response is poor. As plant populations increase, grain and dry matter content may decrease, along with nutritive value. Growers in areas with marginal accumulations of corn heat units should take a conservative approach to increasing plant populations until they become more familiar with growing corn.

The application of 90 to 165 kg/ha (80 to 150 lb/ac) of nitrogen in addition to soil nitrogen may be economical in irrigated areas. Corn has a reputation for high nitrogen requirements, but these requirements are based on potential yield as well as plant-available nitrogen resources. Where expected yields are high (Bow Island, Table 11), nitrogen use will be greater, but requirements may not be higher than for other crops in lower heat unit areas (Lacombe). Phosphorus is frequently deficient and potassium is occasionally required. Fertilizer levels should be determined on the basis of a good soil test.

Granular fertilizer, especially phosphorus, is taken up by seedlings best if it is placed near the seed. However, high application rates, especially of ammonium-based nitrogen fertilizers (includes diammonium phosphate), placed too near to the seed will harm or even kill the germinating seedling. Placing fertilizer 2.5 cm (1 in) to the side and preferably slightly deeper than the seed permits higher application rates (up to 300 kg/ha or 270 lb/ac) without serious injury to the emerging seedling.

Corn is not competitive with weeds. Weeds must be controlled or production will be greatly reduced.

In irrigated areas of Alberta, corn requires a total of about 50 cm (20 in) of water per year. Corn, especially for silage, requires good soil moisture levels throughout the growing season until harvest. Moisture stored from the previous year plus winter and spring precipitation usually provide enough water until mid-June. The water requirements of corn are high from mid-July to early September, and irrigation is very necessary at that time. The most critical time for moisture is during the tasselling to grain filling stages. Since corn is tall growing, either a centre pivot or surface irrigation must be used.

An analysis of long-term precipitation at Lethbridge indicates that for the average growing season, 20 to 30 cm (8 to 12 in) of water should be supplied by irrigation. Most other corn growing areas of the prairie provinces require more irrigation than Lethbridge.

Corn should be harvested for silage when the whole plant is at 60 to 70 per cent moisture. At this stage, the maximum energy per hectare (or acre) will be harvested. This stage is best identified by determining the whole plant moisture content using an accurate balance and the microwave oven method for moisture content (see Table 21 in the *Harvesting* chapter).

Where corn is adapted, the stage of kernel development may be used as an indication of optimum harvest time. Kernel development is described in terms of indentation of the kernel (for dent-type endosperm) and kernel milk line. For corn grown in Minnesota and Wisconsin, early dent, one-quarter milk line, two-thirds milk line and black layer refer to 30, 33, 35 and 42 per cent whole-plant dry matter of the silage, respectively. Optimum harvest time occurs between one-quarter and two-thirds milk line; corn kernels are mature at the black layer stage.

However, in Alberta, corn may not reach the early milk line stages in some years, particularly in areas with less than 2100 accumulated corn heat units. In these cases, whole plant dry matter may not reach 30 per cent before frost. In southern Alberta, corn may dry rapidly after frost, moving from 75 to 55 per cent moisture in a very few days. If this occurs, harvest should be carried out rapidly. Forage nutritive value does not decline much due to weathering from frost per se, but fermentation may be compromised, oxygen exclusion may not be adequate and excessive oxidation losses from silos may result. A combination of frost, rain and prolonged exposure to the elements after frost will result in a reduction of nutritive value. Corn that is more mature appears to have more resistance to weathering than corn that is immature when frozen.

Corn contains enough water-soluble carbohydrates to ensure successful ensiling, although levels do drop in more advanced stages (see Table 1 in the *Ensiling Process* chapter). It has a low buffering capacity, so less acid is required to lower the pH of the ensiled material (see Table 2 in the *Ensiling Process* chapter).

Corn silage has high energy levels but is fairly low (6 to 10 per cent) in crude protein (Table 6). Nutritive value of corn silage is improved with kernel maturity, optimizing near the two-thirds milk line stage. Thus in Alberta, corn silage produced in areas where corn heat units are adequate for varieties chosen should have a higher nutritive value than corn silage grown in areas where it must be harvested at an immature stage. As ears fill, whole plant corn silage neutral detergent fibre (NDF) and acid detergent fibre (ADF) decrease. Digestibility remains about the same, but amounts of digestible starch increase until the two-thirds milk line. In dairy cows fed with corn silage, milk production may increase slightly up to the two-thirds milk line of kernel development.

Table 12 illustrates the effects of improved potential production for well eared corn silage at Bow Island, an area of higher corn heat unit accumulation than Brooks, and in relation to other crops using the MILK95 spreadsheet, developed at the University of Wisconsin. Spreadsheets such as MILK95 and 2001 are good ways for comparing silage yield and quality options in terms of milk production, but may be overly simplistic and may not entirely replicate specific on-farm operations.

**TABLE 12**

**Per cent protein, digestibility (IVDOM), neutral detergent fibre (NDF), estimated daily dry matter digestible (DDM) intake, and milk yield per tonne of forage consumed and per hectare of forage produced for four corn, one triticale, two semi-dwarf barley and one oat varieties at Bow Island and Brooks, Alberta**

| Crop | Protein(%) | IVDOM(%) | NDF(%) | Estimated DDM intake (kg/day) | Estimated milk yield (kg/t forage consumed) | Estimated milk yield (kg/ha forage produced) |
|---|---|---|---|---|---|---|
| **Brooks** | | | | | | |
| Corn | 7.4 | 69 | 47 | 7.3 | 715 | 9,153 |
| Triticale | 10.8 | 63 | 49 | 6.4 | 496 | 3,682 |
| Barley | 12.4 | 71 | 43 | 8.2 | 831 | 7,620 |
| Oat | 11.4 | 55 | 53 | 5.0 | 417 | 1,277 |
| **Bow Island** | | | | | | |
| Corn | 6.9 | 69 | 45 | 7.8 | 751 | 10,606 |
| Triticale | 12.7 | 63 | 50 | 6.4 | 475 | 1,816 |
| Barley | 12.8 | 73 | 45 | 8.2 | 816 | 4,041 |
| Oat | 12.3 | 59 | 52 | 5.4 | 321 | 1,519 |

Estimates are based on 615 kg cow in mid lactation producing 29 kg milk per day, supplemented with barley and soybean meal according to MILK95 spreadsheet (University of Wisconsin). Corn heat units from planting until harvest were 2419 for Bow Island and 2362 for Brooks.

Corn can be grown continuously provided that weeds, insects and diseases do not become a problem and fertility levels are kept high. Harvesting corn silage leaves very little crop residue. Therefore cultivation methods such as minimum tillage should be used to reduce wind erosion and to maintain soil structure.

## Annual legumes

### Field peas

Field peas are cool season annual legumes. They are recommended for silage production in the Black and Thin Black soil areas and in the irrigated areas. Field peas should be grown in areas of higher soil moisture or higher growing season precipitation. They can produce good silage yields under good moisture conditions in the Grey Wooded and Dark Brown soil areas. Since field peas have limited root systems, they lack tolerance to extreme drought or hot weather. High temperatures during flowering cause flower blasting, which results in decreased pod set. This is significant for silage production since pod development makes up part of the yield.

Field peas do best on loam, clay loam and sandy loam soils. Soils with poor internal drainage or cold soils (such as organic soils) are not well suited to field pea production since seeding and root diseases are more prevalent under these conditions. Soil pH should be between 5.5 and 7. Saline soils should be avoided since this crop has a low tolerance to soil salinity.

Peas should not be grown on land that has produced legumes or oilseeds in the past four years, to reduce the possibility of soil-borne diseases. Field peas are therefore most suited to following continuous cropping with crops such as cereals.

The decision to grow field peas for silage should be based on the need for higher quality rather than yield. Peas yield a higher percentage of protein, are highly digestible and have excellent energy (Table 13). Peas generally yield less total dry matter than cereals when grown alone (Table 6).

**TABLE 13**

**Nutritional characteristics and milk production of field pea silage and silage when used in a dairy ration***

| | Alfalfa | Field pea |
|---|---|---|
| Crude protein (%) | 15.3 | 16.7 |
| Neutral detergent fibre (%) | 52.1 | 47.5 |
| Acid detergent fibre (%) | 35.4 | 25.5 |
| Digestible dry matter (%) | 72.4 | 76.6 |
| Digestable energy (Mcal/kg) | 3.21 | 3.37 |
| Dry matter intake (% of body weight) | 2.71 | 2.00 |
| Milk production (kg/day) | 31.4 | 32.6 |
| Butterfat (%) | 3.12 | 3.21 |

*Barley silage was included in both rations.
Source: Aasen et al. (1992)

Field peas should be seeded as early as possible in May when the soil temperature has reached 4 to 5°C at depth of seeding. The seedlings have good tolerance to frost and can regrow from buds below the soil surface if the main shoot is killed by severe frost. Early seeding helps to avoid flower blast since the full flower stage is reached before the heat of summer (i.e., before mid-July).

Early shallow cultivation is recommended to control weeds and warm the soil before seeding but still conserve moisture and keep the seedbed firm. A seeding depth of 5 to 10 cm (2.0 to 4.0 in) is recommended. Conventional seed drills are satisfactory for seeding, although they must be adjusted carefully to avoid cracking or chipping seed, especially with larger seeded varieties. Slow travel speed while seeding decreases seed damage and helps maintain an even seeding depth.

Field pea seeding rates for silage are 75 plants/m$^2$ (7 plants/ft$^2$). To account for the variability in seed size between varieties, use the following formula to determine the proper seeding rates:

$$\text{Seeding rate (lb/ac)} = \frac{\text{(desired number of plants/ft}^2 \times 1000 \text{ kernel weight} \div 10}{\% \text{ germination}}$$

Seed should be treated with recommended fungicides to control fungal diseases. Field peas must be inoculated or seeded with the appropriate rhizobia to enable them to fix atmospheric nitrogen. Soil tests should be used to determine phosphorus, potassium and sulphur requirements.

Field peas are poor competitors, and weeds will affect yields. Recommended herbicides should be used to control weeds early (Figure 21).

**FIGURE 21**
**Effect of timing of weed removal of pea yields**

Grain yields are compared to removal at time of crop emergence.
Source: *Pulse Crops of Alberta*, Alberta Agriculture, Food and Rural Development; K.N. Harker, Agriculture and Agri-Food Canada, Lacombe.

**FIGURE 22**

Peas are grown for high protein silage.

Field peas are sensitive to moisture stress during flower production and pod set. The total water requirement of field peas from all sources of water, including stored moisture, rainfall and irrigation, is 450 mm (18 in). If 200 mm (8 in) of moisture is available from soil storage and precipitation, then another 200 to 250 mm (8 to 10 in) of irrigation water should be applied for good yield. Excessive irrigation on poorly drained soil will encourage disease development.

There are several types of field pea and they can all be used for silage (Figure 22). The most common types grown in Alberta for silage production are the yellow seeded, green seeded and maple or pigeon pea. Both the long-vined indeterminate and the short-vined determinate peas can be used for silage. Peas can also be either leafed or semi-leafless, both of which make good silage. The semi-leafless types have no leaflets on the leaf axil but have large stipule leaves.

The most common types of field pea used for silage are the forage type, which are generally small seeded and have indeterminate growth characteristics, and the grain type, which can vary in size among varieties and have determinate growth. To reduce seeding costs, small seeded varieties are preferred. In silage trials, the forage type out-yielded the grain type in the drier areas of the province, whereas the grain type out-yielded the forage type in moister areas (Table 14).

**TABLE 14**
**Whole plant yields of forage and grain type field peas[1]**

| Pea type | Lacombe[2] (kg/ha) | Brooks[2] (kg/ha) | Edmonton[3] (kg/ha) | Barrhead[3] (kg/ha) |
|---|---|---|---|---|
| Forage | 5,864 | 7,003 | 8,890 | 10,300 |
| Grain | 7,430 | 10,199 | 8,830 | 8,920 |

[1] Pooled values of varieties
[2] H. Najda and A. Aasen, Alberta Agriculture, Food and Rural Development, Brooks and Lacombe, 1998 - 1999.
(Brooks site was irrigated.)
[3] K. Lopetinsky and S. Blade, Alberta Agriculture, Food and Rural Development, Barrhead and Edmonton, 1999 - 2000

Field peas should be harvested for silage between the flat pod and full pod stages. The forage or indeterminate type field peas are generally later in maturation than the determinate types. This later maturity allows the forage type peas to generally be harvested when the peas are still in the flat pod to early filling stage. At the flat pod stage, the quality is very high. The long vines of this pea type add to the silage yield.

**FIGURE 23**
**Time of cutting vs. yield for peas and barley**

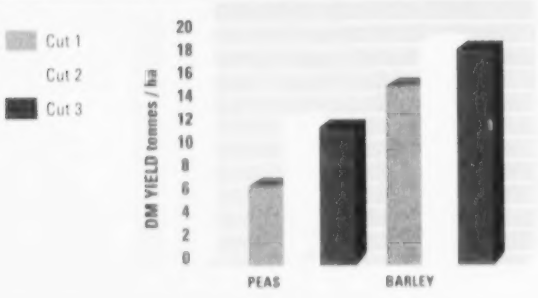



**FIGURE 24**
**Time of cutting vs. per cent protein for peas and barley**

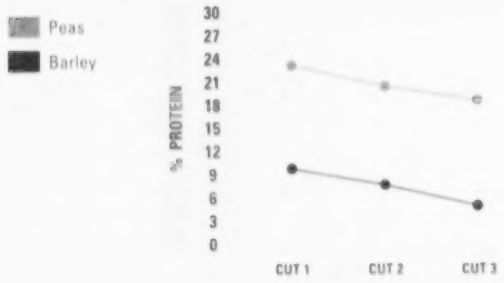
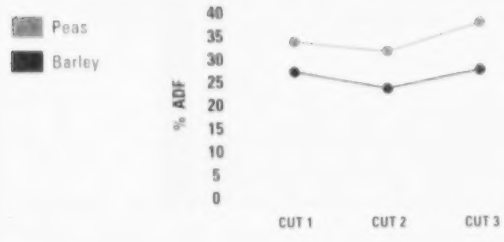



**FIGURE 25**
**Time of cutting vs. acid detergent fibre for peas and barley**




**NOTES** **Notes for Figures 23, 24 and 25**

- Cut 1 – peas flowering and bottom pods beginning to fill.
- Cut 2 – peas finished flowering, bottom pods filled and top pods filling and barley is in mid-dough stage.
- Cut 3 – peas finished flowering, top pods filled and bottom leaves beginning to yellow.

The stage for harvesting the determinate or grain type field pea for silage is when the plants are finished flowering and the top pods are filling. The grain type pea has shorter vines and by allowing the pods to fill, the silage yields can be increased (Figure 23). When the peas are cut after the flowering stage (Cut 2), the bottom pods are filled and the top pods are filling. Dry matter yields at this stage are higher than cutting at flowering (Cut 1) and similar to cutting when the top pods are filled (Cut 3). As the peas mature, the protein levels decrease (Figure 24). The fibre levels in the silage, as indicated by the per cent acid detergent fibre, decrease between Cut 1 and Cut 2, but increase from Cut 2 to Cut 3 (Figure 25). As the pods fill, the fibre level is reduced by the addition of the peas in the silage (Cut 2), and as they begin to reach maturity, the fibre levels in the stem and leaves increase (Cut 3).

Low cutter bar heights, lifter guards (Figure 26) and pick-up reels should be used to cut peas, which lodge easily and are difficult to swath. The long-vined forage pea lodges more easily than the grain type pea, which has been developed for more upright growth. Pure peas are more difficult to ensile than cereals since water-soluble carbohydrate levels are low, buffering capacity is high, and moisture content is high. Before ensiling, the crop must be wilted to 55 to 65 per cent moisture.

### Pea mixtures

Since peas are poor competitors, they yield best when grown alone in pure stands. Figure 21 indicates seed yield losses when weed control is delayed. Similar losses can be expected when peas are grown with other crops in a silage mixture.

**FIGURE 26**

**Lifter guards are helpful for harvesting peas.**

There are some advantages to growing field peas in mixtures with cereals:

- higher silage yields from mixtures than field peas grown alone
- increased feeding quality of the silage, compared to cereal silage
- reduced nitrogen fertility needs of the silage crop
- improved silage fermentation of the peas
- reduce lodging of the peas

Crops grown in mixtures will generally increase the limitations of one of the crops in the mixture while reducing the benefits of the other crop in the mixture. Silage yields of a pea/cereal mixture are generally higher than peas grown alone, but are less than cereals grown alone. Silage quality of a pea/cereal mixture is generally higher than cereals grown alone, but lower than peas grown alone (Figure 27). Pea/cereal mixtures will produce a lower yield of higher quality silage than cereals grown alone and a higher yield of lower quality silage than peas grown alone. Figures 23, 24 and 25 show barley yields and quality in relation to peas yields and quality. When the peas reach the ideal stage for silage, the barley is in the mid-dough stage of development, which is good for silaging (see notes for Figures 23, 24 and 25).

**FIGURE 27**

Pea/barley mixes are grown to increase quality.

To maintain the quality provided by the field peas, cereal seeding rates should be restricted. In mixtures, seeding rates of peas should remain at 75 plants/m$^2$ (7 plants/ft$^2$), and the seeding rates of cereals should be reduced to 25 per cent of normal cereal seeding rates. Cereals seeded at higher rates will be too competitive with the peas, and the benefits of the peas will not be realized (Table 15). Oats and barley are more competitive than wheat and triticale in mixtures with peas.

**TABLE 15**
**Dry matter yield and protein content of pea and barley mixtures***

| | Pea and barley mixtures | | | | |
|---|---|---|---|---|---|
| | Peas + 0 kg/ha barley | Peas + 25 kg/ha barley | Peas + 50 kg/ha barley | Peas + 100 kg/ha barley | No Peas, 100 kg/ha barley |
| Yield (kg/ha) | 7.20 | 7.82 | 7.92 | 8.01 | 7.67 |
| Protein (%) | 13.4 | 12.0 | 11.4 | 11.3 | 9.5 |

* Peas seeded at 75 plants/m$^2$ and barley seeded at 0, 25, 50 and 100 kg/ha.
Source: K. Lupetinsky and S. Blade, Alberta Agriculture, Food and Rural Development, Barrhead and Edmonton

Nitrogen fertility rates of the mixtures should be limited to 50 lb/ac of total nitrogen (soil nitrogen plus applied nitrogen). This amount will be sufficient to allow the peas and cereals to establish, without restricting nitrogen fixation by the peas or creating excessive competition from the cereals.

Using cereals to prevent lodging of peas works in some instances, but it is generally not very effective. The long-vined forage varieties and the high grain producing varieties when grown in mixtures for silage will generally cause both the peas and cereals to lodge.

Growing the two crops in adjacent strips and harvesting across these strips can make an effective pea-cereal mixture. This method makes fertilization and weed control for each crop easier than when growing mixtures. It also permits taking full advantage of the legume in the rotation, provided the strips of peas are wide enough to make up a large portion of the silage.

The use of a cereal/pea mixture will improve silage fermentation. The cereals in the mixture increase the water-soluble carbohydrates of the silage. This speeds up fermentation, reduces the effects of the higher buffering capacity of the peas and reduces the risk of fermentation failure. Although peas are low in water-soluble carbohydrates and high in buffering capacity, they can easily be ensiled without the addition of cereals, if proper ensiling procedures are followed (see *Ensiling Process* chapter).

The feed quality of peas is similar to that of alfalfa, with a low acid detergent fibre (ADF) and low neutral detergent fibre (NDF), and a high digestibility (Table 13). When pea silage was used in a dairy ration as a replacement for alfalfa, there was no substantial difference in production of milk and butterfat.

### Fababeans

Fababeans are upright-growing annual legumes that are resistant to lodging and are very sensitive to drought. This crop is recommended for silage production in the Black and Grey Wooded soil areas and in irrigated areas.

The main advantage of this crop for silage is its high quality, especially the high protein content. Field peas out-yielded fababeans in most of the province except in the Black soil areas in central Alberta. Fababeans produce silage with a slightly higher protein content (Table 6). However, fababeans have a lower dry matter yield than most other crops (Table 6), a higher seed cost, and are more difficult to ensile than cereals.

Fababeans do well on most soil textures provided moisture is adequate, although deep medium-textured soils are preferred. Fababeans tolerate more flooding than most crops, although growth is affected by lengthy flooding. This crop does poorly on shallow soils with a compacted layer near the surface, such as Solonetzic soils. They are sensitive to salinity (i.e., electrical conductivity over 3 mmhos/cm).

Fababeans are legumes that fit well into most crop rotations. The crop is generally grown after a cereal, rather than on summer fallow or following other nitrogen-fixing crops or oilseed crops. If diseases become a problem, a rotation with five years between fababeans and any other affected crop should be used.

Fababeans should be planted as early as possible in northern and central regions (i.e., before May 7), and by mid-May in irrigated areas for best yields. Fababeans are a long season crop requiring approximately 126 days to maturity. The seedlings are fairly frost tolerant (i.e., to -4°C). They can regrow from buds below the soil surface if the first growth is killed by frost. The seedlings lack competitive ability and should be seeded where weeds are under control or can be controlled with herbicides. The seedbed should be moderately firm with good moisture content. A seeding depth of 5 to 10 cm (2.0 to 4.0 in) to good moisture will result in even emergence of the stand.

A seeding rate of 40 plants/m$^2$ (4 plants/ft$^2$) with a row space of 15 to 18 cm (6 to 7 in) is recommended. To account for the variability in seed size between varieties, use the following formula to determine the proper seeding rates:

$$\text{Seeding rate (lb/ac)} = \frac{\text{(desired number of plants/ft}^2\text{)} \times \text{1000 kernel weight} \div 10}{\%\ \text{germination}}$$

Provided there is good germination and emergence, this seeding rate and row spacing should result in about 400,000 plants/ha (160,000 plants/acre).

The seed drill must be adjusted for easy flow of seeds. Use a slow ground speed to avoid hairline cracks on seed as these cracks decrease germination and seedling vigor. A slow ground speed also makes deep seeding more consistent.

Inoculate seed with the proper inoculant to ensure optimum nodulation and nitrogen fixation. Fababean rhizobia are noted for high nitrogen fixation, and fababeans should be grown on low nitrogen soils. The phosphorus, potassium and sulphur needs should be determined by soil testing.

Fababeans are very poor competitors, and weed control is essential to obtain acceptable yields. Herbicides are necessary, and spraying should be done early.

For irrigated production, fababeans are very responsive to the application of full water requirements. The soil should not be allowed to become drier than 60 per cent of field capacity to a depth of 75 cm (2.5 feet). A fababean crop for silage uses about 580 mm (23 in) of water for good yield. If 200 mm (8 in) of water is available from soil storage and precipitation, then 380 mm (15 in) of irrigation water will be required. Since the crop can reach a height of about 1.8 m (6 ft) under irrigation (depending on the variety), it is best to use pivot or flood methods.

Fababeans should be swathed when one or two of the bottom pods on one-quarter to one-third of the crop have turned brown. This stage gives a maximum yield of energy and protein per hectare (or acre). Wilting is still very necessary at this stage, and the fababeans must be allowed to wilt to 65 per cent moisture.

The crop is difficult to ensile due to its high moisture content, low percentage of water-soluble carbohydrates and its high buffering capacity (see *Ensiling Process*). Fababean silage is very dark in color, but livestock eat it readily.

### Fababean mixtures

The low dry matter yield, high quality, and difficulty in making good silage with pure fababeans make the use of a cereal mixture a likely compromise. For mixtures, the cereal seeding rate should be decreased to 25 per cent of the normal amount. The fababeans should be seeded at a normal rate for the variety, as the yield loss resulting from competition is significant. The mixture will have a protein and energy content intermediate between the cereal and fababeans, depending on the final composition of the mixture.

Triticale and wheat are somewhat less competitive, allowing a higher fababean component compared with oats or barley. Fababeans yield less in a cereal mixture than field peas. It should be noted that only a limited number of herbicides are available for weed control of crop mixtures.

An alternative to growing fababeans with cereals in a mixture is to grow each in a pure stand in fairly wide strips adjacent to each other. The crops can be harvested across the strips with each load of silage containing both crops. The strips should be wide enough to maintain from year to year in rotation and to take full advantage of the nitrogen fixation from the fababeans. This approach also permits delayed seeding of the cereals to allow for the long growing season of the fababeans and correct fertilization of each species, with special emphasis on nitrogen for the cereal and phosphorus for the legume.

## PERENNIAL GRASSES

Many cool season perennial grasses are adapted to Alberta. The most widely grown perennial tame grasses include smooth brome grass, timothy, meadow brome grass and orchard grass. Tame and native grasses are fairly easy to ensile since they are low in buffering capacity and high in dry matter content. The percentage of water soluble carbohydrates varies from species to species, but levels are adequate in most cases for ensiling (see *Ensiling Process*). Grasses are generally easier to ensile than legumes because grasses have more water-soluble carbohydrates and a lower buffering capacity.

Proper nitrogen fertilization is important to obtain high yields and quality. As applied nitrogen levels are increased, yield and per cent protein levels (or nitrogen concentrations) increase (Table 16). This increase in nitrogen concentration reduces the amount of water-soluble carbohydrates produced. The lower the water-soluble carbohydrates, the less plant sugars are available for lactic acid fermentation in the ensiling process (see *Ensiling Process*). High nitrogen concentrations can affect the ensiling process.

**TABLE 16**

**Effect of nitrogen fertilizer on dry matter yield and protein of smooth brome grass in central Alberta**

| | Level of nitrogen applied annually (kg/ha) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | 300 |
| Dry matter yield (t/ha) | 3.86 | 5.98 | 7.54 | 8.49 | 8.7 | 8.73 |
| Crude protein (%) | 11.2 | 11.6 | 13.0 | 14.4 | 15.2 | 15.8 |

Source: Malhi et al. (1993)

In the early stages of maturity, from the heading to bloom stages, grasses are medium in quality (protein and energy). However, quality drops rapidly as maturity advances (see *Evaluating Silage Quality*). Dry matter content increases with advancing maturity so that a shorter chop or mixing with more moist material may be necessary if more mature grass must be ensiled.

Grasses vary in their water-soluble carbohydrate content (see Table 1 in the *Ensiling Process* chapter). The water-soluble carbohydrate content may be 6 to 25 per cent of the dry matter in grasses. This variation may be due to maturity, species, variety, fertility, light intensity and temperature (see *Ensiling Process*). As grass matures, the peak level of water-soluble carbohydrate is just before or at heading. Late maturing orchard grasses have been shown to have higher water-soluble carbohydrate levels than early maturing varieties.

Timothy requires careful timing for harvest. Cutting during the boot stage reduces root carbohydrate storage significantly, which weakens the timothy stand. Timothy has a slightly lower protein content than most other grasses, so cutting should not be delayed too long.

Other tame grasses can be harvested at the boot stage if a higher than normal nutrient content is desired. Cutting at this stage will increase silage quality but will reduce crop yield.

Overall crop management of grasses for silage is similar to that for hay production. Additional information may be found in the Alberta Agriculture, Food and Rural Development publications *Alberta Forage Manual* (Agdex 120/20-4) and *Varieties of Perennial Hay and Pasture Crops for Alberta* (Agdex 120/32).

## PERENNIAL AND BIENNIAL LEGUMES

Legume crops are very high in quality, and when properly ensiled they produce excellent silage. However, they are low in water-soluble carbohydrates, high in buffering capacity and have a high moisture content, making them difficult to ensile (see Tables 1 and 2 in the *Ensiling Process* chapter). As with grasses, the higher the nitrogen concentration (protein) of legumes, the lower the water-soluble carbohydrates will be. Swathing and wilting are necessary to reduce the moisture content before ensiling. The use of grass-legume mixtures improves the silage making potential, although it generally results in lower protein and energy levels in the feed.

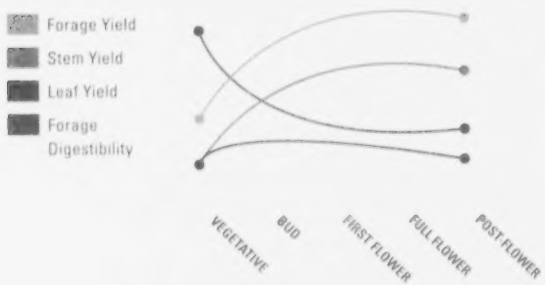
### Alfalfa

Alfalfa is widely adapted and can be produced in all soil zones of Alberta. It requires good internal soil drainage. It is does not tolerate acidity (pH below about 6.0); as the soil pH decreases, alfalfa yields decrease.

The general comments on ensiling legumes apply to alfalfa. However, alfalfa is not as difficult to ensile as most other legumes. It has a higher dry matter content than common clovers such as red clover. This should not, however, be interpreted to mean that alfalfa is easily ensiled. Close attention to wilting and packing procedures, etc., is required to make good alfalfa silage.

Alfalfa is noted for its high forage yields and very high quality. When cut between bud and 10 per cent of the plants showing first bloom, alfalfa has a crude protein content of approximately 17 to 25 per cent. As alfalfa matures, the forage yield increases at the expense of quality (Figure 28). Most of the yield increase after the bud stage is from stem growth, which is less digestible and therefore lowers the silage quality.

**FIGURE 28**
**Forage yield in relation to forage quality**




To maintain persistence of the alfalfa stand, cut at first flower to 10 per cent flowering. This method allows the roots to build up their energy levels by increasing the root carbohydrates. Cutting at bud stage will increase forage quality but may reduce stand longevity. Cutting during the four weeks before a killing frost can also harm stand longevity because it lowers these same root carbohydrates needed to maintain winter hardiness and initiate new spring growth.

Growing alfalfa for silage is much the same as growing alfalfa for hay production. The same management is needed to establish and maintain a high-producing stand.

### Red clover

Red clover is adapted to the moister areas of Alberta. It does well in the Grey Wooded and Black soil zones. It is more tolerant of acidity than other legumes (tolerant of about pH 5.1).

Red clover is very difficult to ensile owing to its low water-soluble carbohydrate content, combined with its very high buffering capacity and very high moisture content (see Tables 1 and 2 in the *Ensiling Process* chapter). Substantial wilting is necessary but is difficult to do without spoilage. Rotten leaves, which may be present due lodging or lying in the swath too long, can infest the silage with undesirable microorganisms.

Cutting red clover at the early bloom stage results in a crude protein content of 15 to 17 per cent. Harvesting at a later stage of maturity (e.g., full bloom) results in somewhat lower moisture levels, but it also means that quality is lower.

Other common clovers, including alsike clover and white clover, are similar to red clover in their ensiling properties.

### Sweet clover

Sweet clover is a biennial legume adapted to all soil zones of Alberta (Figure 29). It requires good internal soil drainage and is intolerant of acidity (below about pH 6.0). Sweet clover is very high yielding, and ensiling is an excellent way to harvest this crop. Sweet clover weevils are a problem where sweet clover is grown frequently.

FIGURE 29

Higher moisture crops, especially legumes, must be wilted to reduce their moisture content.

Sweet clover is generally seeded with a silage or greenfeed cover crop since it is not productive in the year of seeding. The development is slow, although the plant develops a strong tap root. Crown buds are initiated on the root in the fall of the seeding year. In the following spring, the new growth is from these buds, and any regrowth is from the buds on the stem. If a second growth is desired, cut the sweet clover high enough to allow for some stem buds to develop. This is generally 15 to 30 cm (6 to 12 in) in height.

Sweet clover should be harvested when 10 to 20 per cent of the plants show first bloom. If left until full bloom, sweet clover becomes very stemmy and much lower in quality.

Ensiling sweet clover is similar to ensiling alfalfa. The resulting silage is more palatable than sweet clover hay. However, the silo must be carefully covered and sealed to avoid mould formation. Adding a layer of cereal silage at the top of the silo will prevent contact with the air and so minimize spoilage. As with hay, mouldy sweet clover silage can result in high levels of dicoumarol production, which causes bleeding diseases (sweet clover disease) in livestock. Low coumarin varieties should be used.

Overall, legume crop management is similar to that for hay production. Additional information on these and other tame legume crops can be found in the *Alberta Forage Manual* (Agdex 120/20-4) and *Varieties of Perennial Hay and Pasture Crops for Alberta* (Agdex 120/32).

## MISCELLANEOUS SILAGE CROPS

### Canola

Canola can be used as a silage crop, although it is generally only used when it is frozen, affected by drought or too weedy to produce good seed yields. The "industrial oil" type canolas should not be used for silage. Although canola is palatable, livestock may take a few days to adjust to it.

Canola averages 10 to 12 per cent in protein, but the level could increase with increased nitrogen fertility. Total digestible nutrients average 50 to 55 per cent. The feed should be analyzed to determine the actual values for the silage. Seeding at higher rates may reduce stem size and the coarseness of the silage. Nitrates can be very high in canola silage if the crop has been stressed by drought or frost.

To make good canola silage, the crop should be cut when the crop is finished flowering and before the bottom leaves begin to turn color and drop off. Harvesting at this stage will maintain yields without compromising protein and energy levels.

Canola is very high in moisture (about 80 per cent). Canola can be difficult to dry down, and it can be difficult to determine when canola reaches 60 to 65 per cent moisture. Using a crimper while cutting should speed up the drying process. The large, coarse stem retains moisture that can cause the silo to seep effluents. Ensiling at higher moisture levels may increase the butyric acid production in the silage. Canola silage can be layered with cereal silage or placed in the pit on top of the cereals. These approaches will generally reduce the seepage if the canola moisture levels are too high.

Canola silage has low levels of water-soluble carbohydrates. The addition of lactic-acid-producing silage inoculants may enhance fermentation, improve lactic acid production and reduce spoilage of the silage. Canola tends to take on a very dark color when ensiled.

The condition known as haemolytic anemia, which causes the haemoglobin in the red blood cells to break down, is generally not a problem when canola is ensiled. The amino acid compound known as S-methylcysteine sulfoxide (SMCO), which can be found in brassicas, builds up in the plant as it matures. After ensiling, this compound is generally eliminated.

Trace mineral supplementation containing copper and selenium should be fed if canola silage is fed at high levels. Research at Melfort, Saskatchewan, has shown that calves fed high levels of canola had lower rates of gain. Canola silage should be fed at levels no higher than 50 per cent of the total feed intake to reduce feeding problems.

Pesticides applied to canola during the growing season may be residual in canola salvaged for feed. Follow all pesticide labels on feeding restrictions for treated canola.

## Sorghum-sudangrass

Sorghum-sudangrass is not grown extensively on the prairies, but in recent years, hybrids have produced acceptable yields in areas with high corn heat units (CHU) and where moisture is limited. Sorghum-sudangrasses vary in yield, growth habit and prussic acid content depending on the hybrid grown.

The sorghums are warm-season crops and are poor competitors with weeds. Sorghum-sudangrasses do not grow well in low, wet areas because they are not tolerant of cool or saline soils. A well prepared, firm, moist and warm seedbed is best. The ideal time to plant is when the soil temperature has reached 18°C (65°F), usually early June. A warm seedbed is a must to ensure even germination.

Plant sorghum-sudangrass 2.5 to 4 cm (1 to 1.5 in) deep in medium and heavy textured soils. On sandy soils, it may be necessary to plant 4 to 5 cm (1.5 to 2 in) deep to maintain adequate moisture levels near the seed for rapid germination and emergence.

Table 17 provides guidelines for seeding rates. Consult commercial literature for the specific hybrid being planted. If the crop is seeded crossways or diagonally to the planned direction of swathing, the swath will lie on top of the stubble.

**TABLE 17**

**Seeding rate guidelines for sorghum and sudangrass varieties, hybrids and crosses**

| Row spacing and sorghum type | Seeding rate (lb/ac) | |
|---|---|---|
| | Dryland | Irrigation |
| 6-in to 7-in row spacing<br>sudangrass varieties and hybrids, sorghum-sudangrass crosses | 15 to 25 | 30 |
| 30-in row spacing<br>forage sorghum varieties, hybrids and crosses | 5 to 8 | 10 to 12 |
| 36-in to 42-in row spacing<br>forage sorghum varieties, hybrids and crosses | 5 to 8 | 8 to 10 |

Cutting sorghum-sudangrass at the start of tasselling will provide a good balance between protein content and yield. Sorghum-sudangrasses should be wilted before ensiling since they are very high in moisture.

**Hazards with sorghum-sudangrass silage:** Poisoning from prussic acid (HCN) is the greatest risk. HCN poisoning causes asphyxiation. Livestock may be poisoned if they consume large amounts of forage with a prussic acid content above 0.02 per cent. Plants usually have more prussic acid if the soil is high in nitrogen and deficient in phosphorus and potassium, or if the field is under stress by drought or frost. Silage from sorghum-sudangrass can be more safely fed after a storage period of one or two months since the HCN gas escapes during storage and feeding.

A feed test is recommended to determine levels of both prussic acid and nitrates.

## Sunflowers

Sunflowers are recommended for silage production in the Brown, Dark Brown and irrigated areas of the southern prairies (Table 6). Sunflowers give high yields and reasonable quality where they are adapted. As crude fibre is quite high, digestibility is somewhat lower than with most other crops. A three-year comparison at Brooks showed a total yield of 14,930 kg/ha (6.7 ton/ac) for sunflowers, second only to corn. Sunflowers had an ADF of 30.7 per cent and a crude protein content of 16 per cent. Total protein production was second only to the forage brassicas (AHRC 1984).

In the Black and Grey Wooded soil areas, sunflower yields (pure or mixed with cereals) are sometimes high, but they are also highly variable since a long, warm growing season is needed for good growth. Also, a lower protein content has been reported from these areas. Agriculture Canada trials at Lacombe in central Alberta showed an average of 10 per cent crude protein (Agriculture Canada 1984). These factors, combined with the need for specialized equipment, make the production of sunflowers for silage questionable in the Black and Grey Wooded soil areas.

Because sunflowers are late maturing, they should be seeded as early as possible. The minimum soil temperature for sunflower germination is 7°C. Since seedlings are fairly frost tolerant up to the four leaf stage, early seeding is possible. Normal seeding depth

is 2.5 to 5 cm (1 to 2 in), but if large, plump seed is used, a maximum depth of 12.5 cm (5 in) to moisture may be used.

Confectionery type varieties are presently most used for silage production. For silage production, confectionery sunflowers should be seeded at 3.4 to 5.6 kg/ha (3 to 5 lb/ac) depending on seed size. A row space of 30 cm (12 in) is satisfactory. Where precision planting is used, a density of 50,000 to 90,000 plants/ha (20,000 to 30,000 plants/ac) in 60-cm (24-in) rows is recommended. The higher seeding rates produce denser stands with smaller stems. Lodging and disease problems do increase as stand density increases, although these problems are less serious with silage production. Low seeding rates give a slightly lower total yield, and the stems grow larger and are more difficult to handle.

Sunflowers are poor competitors, especially in the early stages of growth. The use of row cultivation and band spraying is possible if wide row spaces are used. (For more information on herbicide recommendations, see Alberta Agriculture, Food and Rural Development's *Crop Protection*, Agdex 606-1, the "Blue Book.")

Sunflowers require high amounts of nitrogen fertilizer with rates of up to 170 kg/ha (150 lb/ac) being economic in irrigated areas. Applications of fertilizer should be based on soil test results.

Sunflowers are frequently affected by diseases and pests. Sclerotinia stalk and head rot may result in wilting of plants. Control measures include using crop rotations and growing resistant hybrid varieties. Sunflower beetles can cause serious leaf damage.

The total water requirement for sunflowers is approximately 500 to 550 mm (20 to 22 in). If 200 mm (8 in) of moisture is available from soil storage and precipitation, then 350 mm (14 in) of irrigation water will be required for good yields. Since sunflowers are tall growing, pivot or flood type irrigation is most suitable.

Sunflowers should be harvested when the backs of the heads turn yellow and the bracts around the head turn brown, but before the bottom leaves drop off. High moisture may be a problem, and since sunflowers don't wilt down well after cutting (they tend to rot), the crop may have to be left until it freezes before ensiling. A fine chop is required to pack coarse stems adequately. As the crop may be 1.8 m (6 ft) or more in height, specialized harvesting equipment may be needed.

Sunflowers have a medium level of water-soluble carbohydrates (see Table 1 in the *Ensiling Process* chapter) and a medium buffering capacity, making ensiling easy.

## Other crops

Almost any crop can be ensiled for livestock feed if it is palatable and contains enough nutrients and moisture to be properly ensiled. Hail-damaged crops, drought-stricken crops or crops that are too weedy and not economic to spray can be ensiled. Some crops that are not common can be used for silage as well.

Hail-damaged cereal crops should be treated in the same way as cereals grown for silage. If the crop is hail-damaged before the hard dough stage and has adequate moisture (60 to 70 per cent) to pack and ensile properly, the crop will make silage. If the hail damage is severe, silage quality will be reduced as there will be fewer heads and leaves in comparison to stems, which are high in fibre and low in protein. Nitrates may also be a problem in silage from hail-damaged cereal crops.

Weedy crops may also be ensiled to produce silage that is comparable to silage from traditional crops (Table 18).

**TABLE 18**
**Nutritive value of weeds and alfalfa**

| Plant | Protein (%) | Digestible energy (Mcal/kg dry matter) |
|---|---|---|
| Alfalfa | 17.6 | 2.54 |
| Lamb's quarters | 17.0 | 2.26 |
| Flixweed | 15.6 | 2.17 |
| Kochia | 15.4 | 1.76 |
| Stinkweed | 15.2 | 1.86 |
| Wild oats | 12.2 | 2.92 |

Precautions must be taken when using weeds for silage. Some weeds may not be palatable, may taint milk in dairy cows, or may be low in minerals. However, harvested in the green stage, most weeds make acceptable silage for livestock.

Kochia is classed as a weed and as a crop. It has been traditionally considered as a weed because once established, it is very difficult to control and it is a very aggressive plant. It has advantages as a crop since it grows very well in saline soils and can yield in excess of 9 tonnes/ha (4 tons/ac) of dry matter. Feed quality is good, with crude protein ranging from 13 to 18 per cent, although the available calcium and phosphorus are not adequate to supply the needs of livestock.

When feeding kochia, livestock should have access to an ample water supply since kochia grown on saline soils is very high in salts. These salt levels may be high enough to cause scouring in livestock.

Forage brassica crops, such as kale and forage rapes, may be used for silage, and they are much the same as canola. Only a limited number of varieties of forage brassicas are available for forage production in Canada. They are late maturing and may not be ready to harvest for silage until September to mid-October, but they tolerate frost well (up to -5°C).

Ensiling forage brassicas is similar to ensiling canola. Forage brassicas are generally very high in moisture (85 to 90 per cent), and it is impractical to wilt them down to 65 per cent moisture. Effluent losses will be very high unless dry matter is added to absorb this excess moisture. Chopped hay or straw can be added, with limited success, but dry barley is best. Even with added dry matter, there still may be seepage and packing problems.

Forage brassicas have a dry matter crude protein content of approximately 16 per cent and a digestibility of approximately 68 per cent (similar to corn silage). Yields are 6.7 to 11.2 tonnes/ha (3 to 5 tons/ac) of dry matter. Forage rape silage is not very palatable, and livestock may require a few days to become accustomed to it, after which it is eaten readily. A diet consisting of only forage brassicas fed fresh to livestock can cause haemolytic anaemia and goitre due to an amino acid compound S-methylcysteine sulfoxide (SMCO). If forage brassicas are ensiled, this toxic factor is generally eliminated.

# Chapter 3: **Silage Additives**

Silage additives have not always proven to be a cost-effective strategy, so producers should look at them very carefully before incorporating additives into a silage system. A range of additives is available. Each has a different purpose and will provide different benefits to the silage.

Silage additives are used to reduce dry matter losses, improve fermentation in the silo, reduce deterioration after the silo has been opened, and improve the nutrient value of the silage.

Good silage can be made without additives if proper ensiling techniques are used. Silage additives may have a place when ensiling crops with a high water content, low level of water-soluble carbohydrates or a high buffering capacity, or when using storage structures that are not well sealed. Also, it may be more convenient to make nutrient additions at the time of ensiling rather than at the time of feeding.

If additives are being considered, the user should first determine the economic feasibility of using the additives. This can be difficult because several factors can affect silage quality. The cost of the additive should be compared to the expected decrease in storage losses and improvements in feeding value of the resulting silage. For example, if it is known that the additive will reduce storage losses by 5 per cent, reduce the risk involved with making the silage under adverse conditions and improve milk production by a significant amount, then an investment in the product equivalent to at least 5 per cent of the value of the forage ensiled is justified.

When making decisions on silage additives, remember that only limited testing has been done on many of the products on the market. Good knowledge of the silage program, the ensiling process and the use of additives in general will help ensure that money is not wasted on products of limited value. Table 19 lists silage additives based on their purpose.

## SPECIFIC SILAGE ADDITIVES

### Fermentation inhibitors

#### Mineral acids

Hydrochloric and sulphuric acid are very effective in reducing the pH of silage. However, they are not recommended because of difficulties in handling these corrosive acids. Silage intake is generally similar to naturally fermented silage. If the silage pH remains in the 3.5 to 5.0 range, it is unlikely that these additives would contribute to a significant decline in ruminal pH. Severe magnesium deficiency can also occur in animals fed mineral acids.

**TABLE 19**
**Types of silage additives**

| Fermentation inhibitors | | Fermentation stimulants | | Nutrients | Aerobic Inhibitors |
|---|---|---|---|---|---|
| Acids | Others | Carbohydrates | Bacteria and enzymes | | |
| Acrylic | Ammonium bisulfate | Glucose | *Aspergillus oryzae* | Ammonia | Propionic acid |
| Acetic | Carbon dioxide | Beet pulp | *Bacillus subtilis* | Beet pulp | Caproic acid |
| Benzoic | Carbon disulfide | Citrus pulp | *Lactobacillus acidophilus* | Calcium | Sorbic acid |
| Citric | Formaldehyde | Molasses | *Lactobacillus bulgaricus* | Carbonate | Pimaricin |
| Formic | Hexamine | Sugar | *Lactobacillus plantarum* | Citrus pulp | Ammonia |
| Glycollic | Paraformaldehyde | Whey | *Lactobacillus buchneri* * | Grains | |
| Hydrochloric | Sodium nitrate | | *Streptococcus brevis* | Minerals | |
| Lactic | Sulphur dioxide | | *Streptococcus faecalis* | Molasses | |
| Phosphoric | Sodium metabisulfite | | *Streptococcus cremoris* | Potatoes | |
| Propionic | Sodium chloride | | *Streptococcus diacetilactis* | Urea | |
| Sorbic | Sodium hydroxide | | *Pediococcus sp.* * | Whey | |
| Sulphamic | Antibiotics | | Enzymes | | |
| Sulphuric | - Bacitracin | | - amylases | | |
| | - Streptomycin | | - cellulases | | |
| | - Bronopol | | | | |

*New additions to table

Sources: Adapted from McDonald (1981), Woolford (1984), and new additions

### Organic acids

**Formic acid** additions increase lactic acid production and suppress clostridial and yeast growth by acidification of the forage. Formic acid treatment has been shown to reduce dry matter losses during ensiling by 2 to 8 per cent. It also reduces protein and amino acid breakdown, which improves utilization of protein in many feeding situations.

Formic acid is particularly effective in improving animal performance with direct-cut silage. The treatment is less useful on silage that has been wilted before ensiling.

The high cost of formic acid has limited its use in silage making.

Formic acid is available in solutions containing 80 to 85 per cent formic acid. Application rates are 2 to 4 L/tonne (1.8 to 3.6 L/ton) of fresh forage for grass silage and 5 to 6 L/tonne (4.5 to 5.4 L/ton) for legume silage.

**Propionic acid** has high anti-fungal properties and also reduces bacterial growth. Application rates of 2.5 to 5 kg/tonne (5 to 10 lb/ton) of fresh forage reduce ensiling losses and improve aerobic stability. Propionic acid is not quite as effective as formic acid and is more costly. It may be practical in situations where aerobic stability is important such as with dry silages.

**Acetic acid** application rates of 3 to 4 L/tonne (2.7 to 3.6 L/ton) of fresh forage or more inhibit clostridial organisms and yeasts. Acetic acid also increases the aerobic stability of silage upon exposure to air. Compared with formic acid, acetic acid is less effective and more costly.

**Acrylic acid** has potential as a silage preservative. When added to forage at about 2.5 kg/tonne (5 lb/ton) of fresh forage, it restricts protein breakdown, reduces fermentation of water-soluble carbohydrates, and improves aerobic stability. The sodium salt, sodium acrylate, is easier to handle than the free acid.

**Benzoic acid** has antimicrobial properties and is used in human food preservation. Its high cost precludes its use in silage preservatives at high levels.

**Sorbic acid** is widely used in the food industry as a preservative. At a concentration of 3 kg/tonne (6 lb/ton) of forage, potassium sorbate inhibits clostridial organisms, yeasts and moulds. It is a comparatively expensive additive. Further experimentation is necessary for it to be recommended for silage, but it may be useful in inhibiting spoilage after removing material from the silo.

### Non-acid fermentation inhibitors

**Formaldehyde** should not be used as a silage preservative. Although this inhibitor is very effective, about 1 per cent of the formaldehyde is transferred into the milk of cows. Formaldehyde is available as formalin, which is 35 to 40 per cent formaldehyde gas and 10 to 15 per cent methanol in aqueous solution. It has strong antimicrobial properties.

**Sulphur dioxide** is a direct acting sterilant that decreases silage bacteria populations, increases the rate of acidification and decreases the breakdown of plant sugars. Application rates are about 3.5 kg/tonne (7 lb/ton).

Sulphur dioxide is a liquid that becomes a gas when released from the application tank. As it is a hazardous chemical to work with, it has little potential as a silage preservative.

**Sodium metabisulfite** is a solid chemical that contains 65 to 67 per cent by weight of sulphur dioxide and releases this sulphur dioxide when it comes in contact with water. The application of this preservative results in decreased sugar loss, decreased protein breakdown, and reduced dry matter loss during ensiling under some conditions. Application rates are in the range of 4 to 5 kg/tonne (8 to 10 lb/ton).

This product is most effective in silages with over 70 per cent moisture and may have a potential use with legume silages. It is not effective when the silage temperature is greater than 30°C, which is one reason it is not effective in dry silages.

**Common salt** (sodium chloride) is not recommended as a silage additive. Although it increases the osmotic pressure and therefore reduces the availability of water to microorganisms, research has shown that it does not improve fermentation in silage.

### Enzymes

Commercial enzyme silage additives consist of a blend of enzyme complexes. These usually include cellulase, hemicellulase, pectinase and α-amylase enzymes, but composition can vary substantially among products. Enzymes are usually combined with microbial inoculants to form silage additives.

Enzymes are added at ensiling to partially degrade fibre to fermentable water-soluble carbohydrates, which provide lactic acid bacteria with extra energy. This process results in faster acidification within the silo and silage with a lower final pH. Also, if enzymes can degrade the more slowly digested fibre within the silage, then increases in the rate of digestion of the silage in the rumen may be expected.

The amount of enzyme activity in the product is usually adjusted so that application rates are between 1 and 5 kg/tonne (2.2 and 11 lb/ton) of fresh forage.

Enzyme activity depends on the type and source of enzymes, silage pH, silage temperature and forage dry matter content. For cellulase enzymes, the pH for maximum activity is between 4.0 and 5.6, whereas for amylase enzymes, activity is the highest between 5.6 and 6.2. Enzyme activity increases as silage temperature increases, but declines as silage dry matter content increases.

Since the outcome of enzyme activity will vary between enzyme complexes, it is advisable to refer to product labels to ensure crop type and silage conditions are appropriate.

### Microbial inoculants

These products are widely used in silage additives. The success of microbial inoculants depends on both the efficacy of the individual bacteria strains in the products and on the application of these products.

Since a rapid drop in pH is desired in the ensiling process and there are often low numbers of lactobacilli on fresh plants, in some circumstances, there is merit in inoculating the forage with lactobacilli to encourage the development of a vigorous lactobacilli population.

Microbial inoculants are not beneficial in the silage making process if the population of lactic acid bacteria on the forage is already large, if the bacterial strains in the inoculum are not well suited to the forage or the ensiling conditions, or if the number of viable microorganisms added is too low.

Microbial inoculants are used to produce a more rapid decline in pH. They may also affect dry matter intake, dry matter recovery and aerobic stability during the feed-out phase.

Inoculant manufacturers have been developing selection criteria that target specific crops, pathogen control or aerobic stability. As a result, microbial inoculants can vary in their effect on the silage fermentation process. Always check product labels to confirm that the inoculant is suited to the silage crop.

Bacteria desired in the ensiling process should be fast growing, produce only lactic acid as an end product of fermentation, be acid-tolerant, work at temperatures up to 50°C, grow in low moisture situations and not degrade organic acids. Examples of suitable bacteria are *Lactobacillus plantarum*, *Streptococcus faecalis*, *Pediococcus cerevisiae*, *Pediococcus acidilactic* and *Lactobacillus acidophilus*.

Another bacterial inoculant, *Lactobacillus buchneri*, is a heterofermentative bacterium that produces lactic and acetic acids. *L. buchneri* has been demonstrated to improve aerobic stability in high moisture silage. This is likely a result of the acetic acid limiting the growth of yeast species responsible for heating following exposure to oxygen.

The cost of microbial inoculants is quite low, and application rates are only in the range of 0.05 to 1 per cent (depending on the dilution of the inoculant) of the fresh forage weight. Therefore, these products can be an economical aid to controlling fermentation.

### Managing microbial inoculants

When selecting microbial inoculants, it is recommended that products purchased be able to provide a minimum of 100,000 colony-forming units (CFU) of lactic acid bacteria per gram of forage. Check product labels for the manufacturer's CFU rating for lactic acid bacteria.

To date, most granular inoculants are applied at 0.5 kg/tonne (1 lb/ton) of fresh forage. Water-soluble products are typically mixed with non-chlorinated water and applied at a rate of 2 to 4 L/tonne (1.8 to 3.6 L/ton) of fresh forage. Generally, liquid-applied products will result in a better distribution of bacteria throughout the forage than granular products.

New dry and water-soluble inoculants are also becoming available as concentrated products. For these products, correct application is even more critical. Consult your inoculant distributor to ensure that existing application equipment can be used. Some concentrated products are sold in conjunction with specific applicator equipment.

Microbial inoculants are generally most useful for crops that are low in sugars or low in natural lactic acid bacteria populations. In some instances, a combination of sugars and microbial inoculants can be useful in the ensiling process.

Field studies indicate that if the inoculant bacteria improve fermentation, then dry matter losses could decline by 2 to 3 per cent and dry matter recovery could increase by 1 to 2 per cent in well-managed silos. But, since the effect of microbial inoculants can vary, it is not advisable to extrapolate results from one inoculant product to another. Clarify product research results with your inoculant distributor prior to the use of any specific product.

#### Molasses and sugars

Molasses and sugars such as sucrose have been widely used as silage additives. Molasses, in particular, is a potentially economical preservative and should be considered when wet legumes are ensiled.

Molasses contains about 50 per cent sugar by weight and is normally added to silage at a rate of 20 to 50 kg/tonne (40 to 100 lb/ton) of forage. The higher levels are recommended for wetter, immature forages and for legumes. Molasses is often diluted with an equal weight of water before use, but this method has the disadvantage of adding more water to silage.

Molasses additions provide microorganisms with additional available sugars. This results in more rapid growth of lactic-acid-producing bacteria and a reduction in clostridial organisms.

### Aerobic inhibitors

Substantial spoilage occurs when silage is exposed to air for periods of 12 hours or longer after being removed from a silo. Additives that improve aerobic stability include propionic acid, acrylic acid, sorbic acid and some microbial inoculants. Ammonia and urea additives improve aerobic stability and also add crude protein to the silage. These compounds are discussed in other sections of this chapter.

### Nutrient additives

#### Cereal grains

Cereal grains (barley, corn, oats, rye, triticale and wheat) have been ground and added to forage to supposedly add available nutrients for microorganisms. Starch, however, is relatively resistant to attack by lactobacilli, thus their growth will not be improved much with ground grain additions. Many endospore-forming organisms such as clostridia can break starch down; thus, grain additions may actually increase the number of spoilage organisms in silage.

In spite of these problems, ground grain is useful in reducing the moisture content of very wet silage and increasing the lactic acid content of silage under some circumstances. Usually the resulting silage is better than silage without additions because the unfermented grain is a good source of nutrients for the animal. However, losses in feed value of the grain during ensiling can amount to 5 to 10 per cent, making this an inefficient way of adding grain to the diet.

#### Liquid whey

Liquid whey is a very cheap feed, and its disposal has been a problem. The product is high in lactose (about 4.4 per cent), and some lactobacilli use lactose as a source of nutrients.

Liquid whey contains only about 6.6 per cent dry matter. This means that it will normally not be useful for ensiling high moisture silages. With mature cereal silages, however, it may be useful to add wet whey.

Dry whey can be added to silage at about 4 per cent of the fresh forage weight.

### Urea

Urea can be added directly to the forage at the time of ensiling to increase the crude protein content of the forage. This practice may be most useful for corn silage and some cereal silages. Usual application rates are 2.5 to 5 kg/tonne (5 to 10 lb/ton) of fresh forage. As much as 25 to 50 per cent of added nitrogen may be lost in the ensiling process.

Urea releases ammonia during ensiling. Ammonia is a base and thus tends to neutralize some of the acid produced, which has the undesirable effect of prolonging fermentation. As a result, there is a lower concentration of acids in silage treated with urea than in untreated silage. But urea application does increase the concentrations of crude protein, true protein, free amino acids and ammonia in silage. Urea nitrogen is incorporated into microbial protein in the ensiling process. The aerobic stability of silage treated with urea may be increased because a greater total fermentation occurs with a corresponding reduction in water-soluble carbohydrates.

In general, animals favor silage with a natural protein supplement over silage treated with urea. The major advantage of adding urea at the time of ensiling is that it can be well mixed with the forage and may eliminate the need for adding a protein supplement at feeding time.

### Ammonia

Ammonia applied to forage at the time of ensiling increases the crude protein content of the forage (Figure 30). Application rates of an aqueous ammonia solution containing 25 per cent ammonia are 5 to 15 kg/tonne (10 to 30 lb/ton). Molasses may also be added with ammonia to increase the amount of sugars in the ensiling material.

FIGURE 30

Adding anhydrous ammonia increases protein content of cereal silage.

Anhydrous ammonia ($NH_3$) is often added to forage at levels of 0.5 to 1 per cent of the forage dry matter (2 to 4 kg/tonne of fresh forage). This is lower than the amounts used to treat straw or preserve high moisture hay. When liquid ammonia is released from a tank, it expands, changes to a gas, and cools the surroundings. An application apparatus is available (Cold-flo™) that uses this principle to keep most of the ammonia cold enough to remain as a liquid until it contacts the forage, thus reducing losses.

Ammonia, like urea, increases the crude and true protein content of forages. Concentrations of organic acids are also increased. Generally, the aerobic stability of the forage increases.

Ammonia additions are economical at the present time with cereal and corn silages, but should not be considered with higher protein silages.

**Anhydrous ammonia can cause severe burns to exposed skin.** Precautions should be taken when applying anhydrous ammonia. Operators should wear protective clothing such as rubber gloves, full-face shields and heavy-duty shoes. A supply of water should be available for flushing off and cleaning accidentally exposed skin.

### Mineral additives

Mineral additives such as ground limestone have been included in silage at 0.1 to 0.3 per cent of the fresh forage to increase the calcium content of the silage. Crops ensiled with limestone have higher concentrations of organic acids and less water-soluble carbohydrates after ensiling since limestone is a base and neutralizes some of the acids produced during fermentation. This practice allows fermentation to proceed for a longer time. A butyric acid type of fermentation can be expected if low amounts of water-soluble carbohydrates are present when limestone is used. However, good silage can be made with limestone additions if enough water-soluble carbohydrates are present. Corn silage, in particular, is deficient in calcium and may benefit from ground limestone additions.

Magnesium compounds have been added to silage to increase the content of this element in silage and thus prevent magnesium deficiencies in cattle.

# Chapter 4: **Harvesting**

Silage harvesting does not always depend on good weather, which is a benefit for producers. Three methods of silage harvesting, direct-cut, wilted and low moisture, give producers some options, depending on the crop and moisture content. Understanding the harvesting systems and importance of length of cut are important factors.

Understanding the basic requirements of an effective and efficient harvesting operation will assist in the production of good quality silage.

Variability in harvesting weather is a problem with any system. However, silage production is less dependent on good weather and fewer harvesting losses are involved, so it is an attractive option compared with other forms of forage harvesting. The weather conditions that can be tolerated depend on the method of silage production and the moisture content at which the crop is harvested.

Silage harvesting can be divided into three categories depending on the crop and the moisture content at which the silage is harvested:

- direct-cut
- wilted
- low moisture

## DIRECT-CUT SILAGE

Direct-cut silage is made by cutting, chopping and immediately ensiling the crop. Direct cutting is best used when the moisture content is approximately 65 per cent or lower (alfalfa in full bloom, grasses fully headed or cereals in the early to soft dough stage).

Most crops cut at the late bud to early heading stage have a moisture content in excess of 70 per cent. This high level of moisture dilutes the acid concentration and results in poorly preserved silage. High levels of moisture can also result in considerable nutrient loss through seepage. Excessive moisture can cause silage to freeze during the winter months.

Crop mixtures such as barley and peas, or barley and fababeans, can be direct-cut when the barley is quite mature. This approach reduces the average moisture content of the mixture.

## WILTED SILAGE

Wilted silage is made by allowing high moisture forage crops to dry in the windrow for several hours or until the moisture content is reduced to the correct level (Figure 31). For example, for conventional horizontal silos, the moisture content should be 65 per cent.

Wilted silage has the following advantages compared with silage that is more moist than ideal for a given system:

- silage preservation is improved
- losses caused by seepage are eliminated when moisture content is decreased to less than 70 per cent
- freezing problems are substantially reduced
- dry matter intake of wilted silage by livestock is greater, so animal production may be improved

**FIGURE 31**

Wilting silage to 65 to 70% moisture content before chopping improves preservation.

In Alberta and Saskatchewan, most crops to be ensiled, except corn, are windrowed to wilt the crop, so it can be ensiled at the optimum stage of maturity and the proper moisture content. Corn silage is generally cut and chopped in one operation.

When making wilted silage, the forage harvester should be set for a shorter cut to permit better packing. The exact setting needed is related to the percentage moisture and theoretical cut versus the actual cut. The operating manual for the harvester usually cites feed roll speed to cut length; most experienced operators look at a sample and decide on the feed roll speeds. An actual cut of about 12 mm (0.5 in) is common.

## LOW MOISTURE SILAGE

Low moisture silage is made by allowing the crop to dry in the windrow until the moisture content is approximately 40 to 55 per cent. Although leaf losses and the risks of field weathering are increased, there are lower storage and freezing losses with well-made low moisture silage.

The main concern in making low moisture silage is excluding as much air as possible. Unless oxygen-limited structures are used, a problem with high temperatures and mould growth during the ensiling process may occur because of air penetration. Thus, it is very important that the forage be finely chopped to about 6 mm (0.25 in) actual cut and be very well packed. Low moisture silage is generally not recommended for horizontal structures.

## HARVESTING SYSTEMS

Once a particular method of silage harvesting is decided on, the type and size of machinery to be used must be determined. A harvesting system with components of matched capacity is vital to the silage making process. To maintain high quality forage and good silage preservation, the harvesting process should be completed as quickly as possible. Delays and stoppages can cause over-drying and quality loss. Equipment should be kept in good working order. Comparative information on the equipment outlined in this section can be obtained from the Ag Technology Centre in Lethbridge or the Prairie Agricultural Machinery Institute.

Silage harvesting systems generally include a windrower, a harvester, and trucks or wagons to transport material to the storage site. The type of storage and the distance involved will often dictate whether trucks or wagons are used. Self-unloading wagons are convenient but have a hauling capacity that is limiting when long distances are involved. When hauling distances are greater than about 1.6 km (1 mile), a high dump wagon with trucks for hauling is more efficient.

### Crop maturity

One of the main advantages of producing silage is that timely harvesting is usually possible. The time to harvest will depend on the crop and its stage of maturity (see the *Crops for Silage* chapter).

Since the speed of harvest is limited by manpower and machinery, it is difficult to harvest large acreages of an entire crop at the optimum stage of maturity. Experienced silage makers know the average daily production of their machinery and crew, and start harvesting before the optimal stage of maturity to avoid overly mature material. Planting crops at different times or using varieties that mature at different times increases the number of days at which the total crop is at optimum maturity.

### Moisture content

The moisture content required for silage depends on the storage system used (see the *Silos* chapter). Since the moisture content of forage fluctuates from day to day or within any one day, it is difficult to keep within the ideal range. In practice, the moisture content of individual cuttings may be on either side of the range as long as the final moisture content is within the range.

The recommended moisture content for silage in conventional horizontal silos is 60 to 70 per cent. Harvesting should begin when the forage reaches 70 per cent moisture. Try to harvest at moistures above 65 per cent to reduce field losses and to reduce the possibility of overheating caused by inadequate air exclusion. Corn silage should be harvested at 62 to 70 per cent moisture, with the ideal being 65 to 68 per cent. When large acreages are involved, some corn can be harvested at over 70 per cent moisture.

To avoid large quantities of forage becoming over-dried, the forage windrower (swather) should not get too far ahead of the harvester. If some crop gets too dry, some high moisture silage, 70 per cent or over, should be placed on top of it in the silo. Seepage should then raise the moisture content of the over-dried forage.

Several methods are commonly used to estimate the moisture content of forages prior to being placed in the silo. The hand or squeeze method to estimate moisture

content of chopped forage is described in Table 20. The microwave oven method to analyze a forage sample for moisture content is described in Table 21.

**TABLE 20**
**Hand method for estimating moisture content of forages**

| Characteristics of forage squeezed in hand | Moisture (%) |
|---|---|
| Water easily squeezed out and material holds shape | 80 |
| Water can just be squeezed out and material holds shape | 75 - 80 |
| Little or no water can be squeezed out but material holds shape | 70 - 75 |
| No water can be squeezed out and material falls apart slowly | 60 - 70 |
| No water can be squeezed out and material falls apart rapidly | < 60 |

**TABLE 21**
**Microwave oven method for determining moisture content of forages**

1. Weigh an approximately 100 g sample of the chopped forage (W1) excluding the weight of the container. Weigh to the nearest gram.
2. Spread the weighed forage sample on a paper plate or place it in a paper bag and put it in the microwave oven.
3. Place an 8 oz glass three-quarters full of water in the oven to prevent ignition of the sample.
4. Heat at 80 to 90% of maximum power for 3 minutes.
5. Remove the sample, mix it and weigh it.
6. Continue to reheat for 2-minute intervals, re-weighing each time. To prevent burning, use lower heat and 30 second time intervals as the sample approaches being dry. If the weight of the sample does not change after two or three drying intervals, it is 100% dry. This is the final dry weight (W2). A slightly charred sample should not affect the accuracy of the moisture determination, but if the sample burns, the test should be repeated.
7. Calculate moisture content as follows:

$$\text{Moisture content} = \frac{(W1 - W2)}{(W1)} \times 100$$

$$\text{Example} = \frac{(100 - 36)}{100} \times 100 = 64$$

The microwave oven method is quick and precise but not always practical. It is often desirable to know the moisture content as conditions change throughout the day. A reliable moisture tester is a useful tool. Several portable testers are available commercially and can provide reliable results. Calibrate and compare portable tester results with the results from the microwave oven method to provide a check on meter accuracy.

## Windrowing

Proper swathing and a uniform windrow with most of the stems placed parallel to the direction of travel are essential to obtaining a short, uniform length of cut with the harvester. Poorly windrowed fields with piled and tangled swaths result in a great variability in the length of cut of the silage.

Direction of travel is important in lodged or leaning grain crops. Cutting in the direction of crop lean generally results in parallel windrows, while cutting at an angle to the direction of lean generally results in angled parallel windrows. To provide uniform swaths in grain crops, the reel should contact the stalks below the head. In light grain and forage crops, the reel should be operated near the cutter bar to reduce bunching.

In tangled and lodged crops, the use of a pick-up reel can reduce losses. Such situations require an experienced operator who is able to adjust travel speed, reel speed and reel raker finger angle to suit specific crop conditions.

Lodged fields often contain areas of standing and semi-lodged crops. In such areas, the reel can become entangled with standing crop while trying to cut the lodged portion. The addition of a push bar in front of the reel can reduce reel tangling. In semi-lodged areas, the push bar bends the standing crop and allows the reel to contact the lodged portion. A push bar reduces losses in semi-lodged areas but produces a tangled windrow. Considerable operator care, experience and patience are required to effectively windrow lodged crops.

The use of mower conditioners increases the drying rate and results in more uniform drying. The use of a conditioner will likely permit harvesting two to six hours earlier, although much variation can be expected owing to weather conditions. Conditioned windrows tend to be fluffy with the stems lying in all directions. This increases the variability in the length of cut and reduces the silage density so that extra packing may be required to ensure safe storage. Mower conditioners are therefore not recommended in cereal crops. They can be useful when cutting legume crops, especially in moist areas.

## Harvesters

Most forage harvesters can be adapted to harvesting different types of crops. Pickups are available for windrowed crops, cutting heads for direct-cut silage, and row crop heads for whole plant harvesting, and some harvesters can use ear corn snapping heads to make ear corn silage.

Most harvesters use either a cut-and-blow or a cut-and-throw system of harvesting. The crop is delivered to the cutter head where it is chopped. Cut-and-throw harvesters deliver material directly to the wagon or truck.

Cut-and-blow harvesters use a separate blower behind or beside the cutter head to deliver the crop to the wagon or truck. Either type of harvester is capable of providing uniformly cut material.

A forage harvester should provide a uniform length of cut with smooth, squarely cut ends while maintaining maximum efficiency. Most harvesting machines are capable of doing a good job provided the knives are sharp and proper knife clearances maintained. Proper preparation, plus careful maintenance and correct operation of the harvester help make the job go smoother and faster. Operator care and attention are a must.

Experienced custom operators strongly recommend rolling the fields right after seeding to put all the rocks out of the picture on all fields. One rock the size of a coffee cup can do a lot of damage to the cutter/chopper and can bring the whole harvest operation to a halt.

#### Length of cut

The optimum length of cut for silage depends on the type of crop and moisture content. For most crops, average actual length of cut should be about 12 mm (0.5 in). Corn silage should usually be 5 to 12 mm (0.25 to 0.5 in) long for best packing and fermentation. Longer lengths of cut can be ensiled provided there is sufficient packing and oxygen exclusion.

As a general rule, the drier the material, the shorter the length of cut has to be. Dry forage is more difficult to pack and must be finely chopped.

Finely chopped forage is easier to remove from silos and handles well in mechanical equipment. The performance of some silage unloading equipment may be adversely affected if a significant amount of the material is longer than 38 mm (1.5 in). Cutting the material any finer than necessary for proper storage or feeding, however, wastes time and power.

For each length of cut setting, a forage harvester produces a range of material lengths. The actual average length of cut should be close to the theoretical length of cut when the stems in the windrow are parallel to the direction of travel. Tangled and bunched swaths produce forage with a wide range of material lengths. For most crops, no more than 10 per cent of the forage should be in pieces longer than 40 mm (1.5 in).

If the range of cut lengths is greater than desired, a recutter screen may be used. A recutter screen reduces the percentage of longer pieces and results in finer and more uniform cut lengths. However, recutter screens increase the power requirements and decrease the capacity of the harvester and are generally not required. Recutter screens reduce harvester capacity by about 25 per cent for the same power input.

#### Harvester power requirements and harvesting rate

The power requirements and work rates of a silage system depend on many factors. Actual harvesting rates depend on the particular harvesting system, tractor power, the size of the harvester and the field operating efficiency. Wagon or truck unloading, headland turning and machinery maintenance times all affect harvest rates and vary with each system. Power requirements increase for shorter lengths of cut. As general rule, harvester power consumption for the same throughput increases by 25 per cent when length of cut is halved. Harvesting rates also vary with crop moisture content. With any system, harvesting rates are higher with heavy, uniform windrows and moisture contents near 65 per cent.

Calculating the harvesting rate is useful for determining the trucking capacity needed or to help in determining custom rates or "good neighbor" charges for harvesting.

The amount of power available to the harvester is a major factor in determining the harvesting rate. For most crops and average field conditions, the tractor or harvester should be operated at about 80 per cent of its maximum rated power. This allows sufficient reserve capacity for hills and soft spots. Pulling a wagon or truck behind the harvester lowers the harvest rate by reducing the power available for cutting. A wagon full of silage in soft, hilly conditions can require up to 20 kW (25 hp).

A rough rule of thumb for sizing a forage harvester to a tractor is 20 to 25 kW/m (8 to 10 hp/ft) of swath in alfalfa and cereals, and 40 kW (55 hp) per row of corn. It is best to match a harvester of high power rating with a similar sized tractor. An oversized harvester is a poor investment.

Harvester throughput rates can also be estimated from the power available to harvester. As a rough rule of thumb, harvesting rates in good conditions for cereal silage can be estimated by dividing the harvester engine power (kW) by three and one-half. For example, output from a 150 kW (200 hp) harvester in cereal silage would be about: $150 \div 3.5 = 43$ wet t/h. For corn and alfalfa, the throughput rates can be estimated by dividing the harvester power by three and four, respectively.

The silage harvesting rate is based on weight, but weight can be difficult to estimate in the field. Often, it is easier to calculate in-field harvesting rates based on volumes. This requires an estimate of silage density and moisture content at the time of chopping, so the weight can be calculated. Dry matter densities vary slightly with crop type and moisture content, but 80 kg/m$^3$ (5 lb/ft$^3$) is a typical value for silage density on the wagon or truck and can be used to estimate throughput rates. Wet or 'as chopped' densities will vary with moisture content as indicated in Table 22. For example, at 65 per cent moisture content, the typical wet or 'as chopped' density would be about 230 kg/m$^3$ (14.3 lb/ft$^3$).

**TABLE 22**

**Wet or 'as chopped' densities at various moisture contents for 80 kg/m$^3$ (5 lb/ft$^3$) dry matter density**

| Moisture content (%) | 45 | 50 | 55 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|
| Density (kg/m$^3$) | 145 | 160 | 178 | 200 | 230 | 267 | 320 |
| Density (lb/ft$^3$) | 9.1 | 10 | 11.1 | 12.5 | 14.3 | 16.7 | 20 |

Thus, to estimate in-field harvesting rates, the volume of chopped forage collected over a given time must be calculated. For example, if a 5.5 m x 2.5 m x 1.5 m (18 ft x 8 ft x 5 ft) truck box were filled with 65 per cent moisture content cereal silage in 7 minutes, the harvest rate would be:

Volume = 5.5 m x 2.5 m x 1.5 m = 21 m$^3$
Weight = volume x density = 21 m$^3$ x 230 kg/m$^3$
= 4.83 tonnes
Rate = weight/time = 4.83 tonnes/7 min x 60 min/h
= 41.4 wet t/h

or

Volume = 18 ft x 8 ft x 5 ft = 720 ft$^3$
Weight = volume x density = 720 ft$^3$ x 14.3 lb/ft$^3$
= 10, 300 lb or 5.2 tons
Rate = weight/time = 5.2 tons/7 min x 60 min/h
= 44.6 wet tons/h

It is often convenient to determine harvesting rates and yields based on the crop dry matter weight. Dry matter yields and harvesting rates consider the amount of dry matter harvested and are independent of crop moisture content. Dry matter yields and harvesting rates allow for comparison of different crops at different moisture contents. Dry matter yields and harvesting rates can be estimated from:

Dry harvest rate = wet harvest rate x
(1 - moisture content)

For the above example, throughput rates for the 150 kW (200 hp) harvester in cereal silage at 65 per cent moisture content would be:

Dry harvest rate = 41.4 t/h x (1 - 0.65)
Dry harvest rate = 14.5 t/h

Knife and shear plate condition and adjustment significantly affect power requirements, quality of cut and wear rate. Sharp knives and properly adjusted shear bar clearances increase knife and shear bar life, increase fuel efficiency and provide for the most uniform length of cut. A general rule is to check and adjust the shear bar and knife clearance at least twice as often as the knives are sharpened. If a recutter is used, screen clearance must also be adjusted precisely and regularly.

## Wagons and trucks

Efficient transport of cut silage from the harvester to the storage site is a must. The most efficient system for each operation will vary depending on the amount of silage to be hauled, the distance involved and the type of storage used.

Tractor-pulled self-unloading wagons are convenient for small operations with short hauling distances and upright silos. One tractor and operator can handle two forage wagons. One wagon is hauled and unloaded while the other is being filled from the forage harvester. This system is satisfactory when hauling distances are less than about 1.6 km (1 mile). Self-unloading wagons are not as convenient in operations with horizontal silos, but can be used for feeding silage.

A popular means of harvesting silage is with a high dump wagon and using trucks for transporting to the silo (Figures 32 and 33). High dump wagons hydraulically raise and tip the silage box high enough to dump the load into an extended truck box. It requires two to four minutes to dump the load into a truck. One truck can keep up to the system when the hauling distance is not over 2 miles (3.2 km). The high dump wagon can eliminate the need for one truck and one man depending on distances involved.

A high dump wagon requires an additional 20 kW (25 hp) to pull, under average conditions, and more with soft fields or hills. The wagons are quite stable if dumped on level ground. Trucks are faster than self-unloading wagons and are more suitable when hauling long distances.

FIGURE 32

High dump wagons and trucks are an efficient means of transporting silage for short distances.

FIGURE 33

A silage dump wagon complements trucks for short hauling distances.

FIGURE 34

Trucks are efficient for transporting silage to the silo.

Trucks lend themselves well to operations with horizontal silos (Figure 34). Operations with upright silos require a blower feeding mechanism. Several types of blower feed mechanisms are available with varying unloading rates.

FIGURE 35

Direct filling can increase harvesting rates.

Some operators prefer to fill trucks directly from the harvester (Figure 35). This method eliminates the need for a wagon but requires sufficient trucking capacity to keep up to the harvester. Skilled operators are required to keep the truck and cutter adequately positioned to reduce losses and to load the truck uniformly. Unbalanced loads can pose a risk during unloading. With skilled operators, harvest rates can be higher with this system due to reduced stopping times. Wagon unloading time can be significant especially with the larger capacity harvesters.

Arranging a well-balanced harvesting system requires care and attention to equipment sizes and matching capacities. The lowest capacity unit determines the harvesting rate of the whole system. Sufficient hauling and silo loading capacity should be obtained to keep the harvester working at full capacity. Typically, three to five people are required to maintain a smooth, continuous harvesting system. It is often convenient to share equipment and manpower among neighbors. This approach reduces individual capital requirements and can provide an adequate labor supply.

## Harvesting system losses and efficiency

Dry matter field and hauling losses can be kept to less than 1 per cent in a good harvesting operation, although losses of 2 per cent are common. Higher losses can occur with careless and inefficient operation of equipment.

To maintain optimum efficiency, use suitable equipment, take precautions to eliminate wind losses, and employ good operators who can maintain high field efficiencies. Follow the manufacturer's guidelines for proper operation, adjustment and maintenance of all equipment to ensure rapid field harvesting and optimum silage condition.

## BALE SILAGE SYSTEMS

Bale silage systems are another method of harvesting silage. Round bale silage systems are common, although square bales can also be used. These systems use a baler and a bagging or wrapping system to bag or seal the bales.

The main advantages of bale silage are low capital investment, low labor requirements and low fuel requirements for baling compared to chopping forage. Baling requires about one-quarter as much energy as chopping. Silage baling can be used as an alternative to hay baling in seasons when the weather too wet to make hay. Crops that can be baled as hay and are reasonably easy to ensile, such as most grasses, cereals or grass/legume mixtures, can be made into bale silage.

Although baled silage systems have a higher potential for spoilage than other silage systems (see Table 23), quality silage can be produced if operators follow proper harvesting and handling techniques with care and good timing. Harvesting and bagging need to be done quickly and properly to minimize spoilage. Adequate packing or bale density is required for proper fermentation. Holes or tears in the plastic bag or wrapping will result in spoilage of the silage; care must be taken when bagging or wrapping and when moving the bales to prevent damage to the plastic. Any holes or tears must be patched to minimize losses.

Bale silage should be harvested at moisture contents between 40 and 55 per cent. Higher moisture contents ensure better fermentation, but reduce the amount of dry matter per bale.

High moisture content bales can be heavy. Bale size should be set to produce a similar weight bale as for dry hay systems. Belt or chain type round balers are best for adjusting the size of bale. Fixed chamber round balers can be used but will produce a heavy bale. Weight for a silage bale at 65 per cent moisture content will be about 2.5 times as heavy as for a similar sized hay bale. Round silage bales should be about two-thirds to three-quarters the diameter of a hay bale to ensure reasonable weights (Figure 36). The bales should be twine tied as for hay.

**FIGURE 36**

**Round silage bales should be 2/3 to 3/4 the diameter of a hay bale.**

Harvesting rates for bale silage are slightly lower than for hay systems. Extra time is required for tying, as the bales are smaller.

The best silage is made when the crop is cut young, wilted to the correct moisture content, then harvested quickly and sealed air tight as soon as possible, preferably within 5 hours but not longer than 10 hours, after baling. The quality of the silage decreases rapidly if the bales are left more than several hours. Bale silage densities are about 240 to 350 kg/m$^3$ (15 to 22 lb/ft$^3$), which doesn't allow for optimum oxygen exclusion. As a comparison, typical silo densities are about 485 to 800 kg/m$^3$ (30 to 50 lb/ft$^3$). Wrapping or bagging must be done quickly and sufficiently to prevent oxygen from entering the forage. Baling when air temperatures are cool, such as in early morning, will slow the start of harmful heating.

Bagging or wrapping takes about five minutes per bale. Some operators find it easier to transport unwrapped bales to the storage site for subsequent wrapping. Bagging or wrapping at the storage site minimizes handling and the chances for damage to the wrapping. For information on bagging and wrapping options for bale silage, see the *Silos* chapter.

# Chapter 5: **Silos**

Storage systems for silage exist in many forms. No one system fits all, so producers must evaluate their needs and costs individually. Silo types can vary from horizontal ones like trench/pit, bunker or stacks, which all need to be covered, to bale or bagged silage, which require wrapping, or vertical systems like constructed tower silos.

## SILAGE MAKING AND STORAGE

The storage system for silage is the most important part of the ensiling process. If the storage system does not perform properly, the quality of the silage will suffer.

There is no silage storage system that will guarantee success. Any system for making silage must be managed properly.

Silage quality varies a great deal. Very good feed may come from the simplest of silo storage facilities. Unfortunately, lesser quality sometimes results in spite of investment in very costly systems. Each manager must have a complete understanding of what is required for forage to ferment into silage. The manager must adapt those requirements to the silo type selected. Finally, if a dedication to making good silage is present, the result will be excellent quality feed from whatever system is selected or designed.

Silage has the advantage of being harvested from the field at a high moisture content. This approach increases both the quality and quantity of feed taken from the field. Unlike baled hay, silage has a moisture content of 40 to 70 per cent. Forage will spoil at this moisture content unless it goes through the process of fermentation to become silage.

The silo storage system serves one main purpose in this process. It helps remove and maintain the exclusion of air (see *Ensiling Process* chapter). In a tower silo, the weight of silage forces the air upward through the silage to the top. After the ensiling process starts, a layer of carbon dioxide ($CO_2$) lies on the silage surface preventing oxygen from entering the silage. **Use life breathing equipment to enter this environment.** For a horizontal silo (trench, bunker, stack), the silage must be packed to exclude air. A heavy tractor driven over the surface forces the air from the silage. A layer of forage or a cover then prevents air from entering the silage. A silage tube packing machine excludes the air as it stuffs the forage into a silage bag.

All silos require proper containment of any silage seepage to prevent the seepage from reaching a watercourse or leaving the property.

### Forage losses

When selecting a forage system, consider forage losses in the field, harvesting, and storage and feeding with various systems. Table 23 provides a summary of the average losses that are estimated to occur under various

**TABLE 23**

**Examples of estimated per cent feed losses from various silage systems under good conditions**

| Type of dry matter loss | Horizontal pit 65% M.C. | Horizontal concrete 65% M.C. | Concrete tower 65% M.C. | Oxygen-limiting tower 45% M.C. | Silage bags (tubes) 65% M.C. | Round bale silage 65% M.C. | Square bale, hay (sheltered) 20% M.C. | Round bale, hay (outside) 18% M.C. |
|---|---|---|---|---|---|---|---|---|
| Respiration and weathering loss | 4 | 4 | 4 | 6 | 4 | 4 | 10 | 12 |
| Harvesting loss | 2 | 2 | 2 | 3 | 2 | 4 | 3 | 5 |
| Storage loss | 15 | 12 (10-15) | 9 (8-9) | 5 | 14 (5-25) | 18 (10-25) | 3 | 6 |
| Feeding loss | 4 | 4 | 2 | 2 | 4 | 4 | 5 | 5 |
| Total | 25% | 22% | 17% | 16% | 24% | 30% | 21% | 28% |

M.C. = moisture content

Notes: Losses are highly variable and can be much higher depending on management and climatic factors. Oxygen-limiting towers and concrete towers are the least affected by these factors. Polyethylene deteriorates with time so systems most dependent on it for excluding oxygen have greater losses with long-term storage.

Sources: Adapted from: McIsaac and Lovering; Hoglund (1964); Agriculture Canada Canadex 120.60; Agriculture Canada Publication 1786E; Muck and Holmes (2001).

systems with good management practices. Much higher losses are possible if good practices (such as mending tears in plastic covers, using concrete floors, etc.) are not followed. See the *Costs of Silage Production* chapter for more information on comparing various systems.

## Horizontal silos

Horizontal silos are less costly to construct and are well suited to feeding livestock in widely separated pens. There are two basic types: below-ground level (trench or pit silos) and above-ground (bunker and stack silos).

### Trench (or "pit") silos

This common silo type is dug into a slope with the "downhill" end open for drainage and access. Earth walls should be sloped at a ratio of 1:2 to prevent caving in and to enable adequate silage packing (Figure 37). Where soil is unstable, it is necessary to line the walls with cast-in-place concrete or, more commonly, tilt-up concrete panels, or treated wood walls with an untreated plywood or plank liner (Figure 38). These walls need to be properly anchored to the bank to prevent them from collapsing inward when the silo is empty.

A convenient width for loading with a tractor and front-end loader is 15 m (50 ft).

A reinforced concrete floor will stand up under high moisture from silage, rainfall and spring thaw. The floor should be sloped at 1 to 2 per cent to the open end for adequate drainage. It is preferable to have the open end facing south.

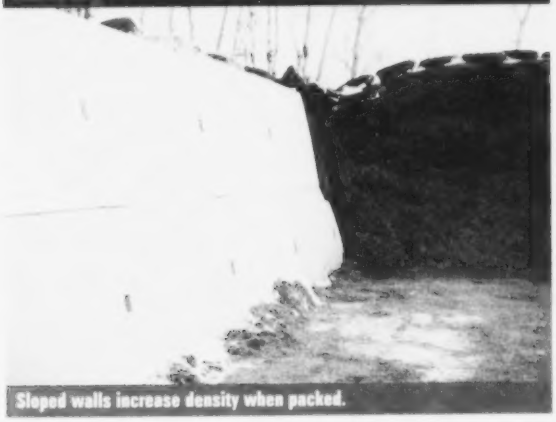
### Bunker silos

These silos are used in flat areas where a trench silo cannot be located close enough to the feeding area (Figure 39). Above-ground walls are constructed using concrete, earth or wood (planks or lowest grade plywood) braced with timbers or concrete buttresses (Figure 40).

**FIGURE 37**

Earth walls for trench silos should be sloped at a ratio of 1:2 to prevent caving and enable adequate packaging.

**FIGURE 38**



Sloped walls increase density when packed.

**FIGURE 39**

Bunker silos can provide effidient storage for large operations.

**FIGURE 40**

Bunker walls must be well braced.

The inside silo lining should not be treated since wood preservatives presently registered in Canada *cannot* be used in direct contact with livestock feed. Permanent wood lining or walls should be covered with plastic to prevent moisture and acid penetration. Walls, end posts and braces must be designed to withstand the pressure of the silage and the packing tractor.

Bunker silos require adequate drainage. Concrete floors are usually needed for easier loading and to minimize feed waste. Where earth floors are used, traffic must be limited (especially animal self-feeding).

Some construction techniques are available in Alberta Agriculture, Food and Rural Development's Farm Building Plan Service. Check the website at **www.agric.gov.ab.ca**.

### Silage stacks

Stacks are best used for storing an unexpected surplus of forage or as an interim method when first trying silage. Silage stacks must be located where drainage is good, such as on a slight crown or parallel to a slight slope.

Where available, large round straw bales braced in place and lined with 6 mil plastic can be used as a temporary wall. The resulting silo would act like an above-grade bunker.

Per cent spoilage is often high, since a stack has a large surface area exposed to oxygen and the weather. A sealed plastic cover is required.

The use of a large stack minimizes the amount of surface spoilage. The most efficient shape is a domed stack. This shape also permits tractor packing over the entire surface. The packing tractor must be operated very carefully.

The width and length of the stack are also affected by the removal rate for feeding. The stack should be sized so that at least 10 cm (4 in) of silage will be removed per day.

A silage making system developed by Agriculture Canada in Kapuskasing, Ontario, called the KAP method, involved forming a silage stack without packing it. This method is used to a degree on the prairies where it is also known as heap silage. It appears to be an effective, low-cost method for making small quantities of silage. Heap silage is useful for preserving unexpected surplus silage or for first-time silage users who do not yet have a permanent silo.

In the heap silage method, cut forage is pushed into a 3.5 to 4.3-m (12- to 14-ft) high pile with a tractor and front loader without packing it. Immediately after piling, the stack must be hand groomed so that a single sheet of 8 mil silage grade plastic fits evenly over it. The plastic must be anchored so that it is held firmly against the pile as it settles (Figure 41). A good method is to suspend tires weighted with sandbags on ends of ropes going over the stack. The plastic cover must also be well sealed at ground level. Sand works well to make the seal and is not as easily washed away as soil, etc. If the plastic seal is good, plant respiration will exclude oxygen from the pile within 24 hours.

**FIGURE 41**

For heap silage, the plastic tarp must be well anchored to stay tight after the silage settles.

### Filling and packing horizontal silos

Filling of a horizontal silo starts at the end opposite the entrance with the pile sloping to the entrance (Figure 42). The cut forage is added to the sloping face in uniform layers. Keep the front slope as steep as the packing tractor can handle without spinning. The quicker that layers of silage can be added, the better.

FIGURE 42

Filling of a horizontal silo starts at the end opposite the entrance, with the pile sloping to the entrance.

The layers are packed into place by a heavy tractor driven on the silage surface (Figure 43). A heavy tractor compresses the silage mass forcing the air out. Pack on deep layers of new silage (i.e., 2 ft or 60 cm). As much packing as possible should be done immediately. The packed surface should feel firm to walk on. If one sinks to the ankle or the step has a spongy bounce, more packing is needed. It is usually difficult to pack the top one or two feet of cereal silage adequately. The next load of silage added will seal air from the packed silage underneath.

FIGURE 43

Visible tire tracks indicate effective packing.

Once packed, the plant material and bacteria will use the remaining oxygen in the silage. Any additional packing would squeeze out the desirable carbon dioxide produced by fermentation and introduce unwanted new air. After a break in harvesting, add new silage before packing.

If equipment can work from the walls (trenches or earth wall bunkers), an alternative to filling from the end is to dump the silage near the wall and push it into the bunker and forward to the leading edge. The silage mass itself with the help of a heavy tractor presses the air from the silage. The tractor must have wide tires to prevent getting stuck in deep silage. This method is most effective when large or several harvesters are working.

Only experienced operators should operate equipment on a horizontal silo or especially on a silo stack. Rollover protection cabs should be used on packing tractors. Wheels should be set as far apart as possible, and tractor speeds should be slow. The tractor should be weighted to have a low center of gravity. Back onto silage piles, and avoid stopping part way up a silage slope.

The temperature of the silage during ensiling is an indicator of the success of harvesting and silo filling. If the silage temperature exceeds 40°C (100°F), look at making the following adjustments:

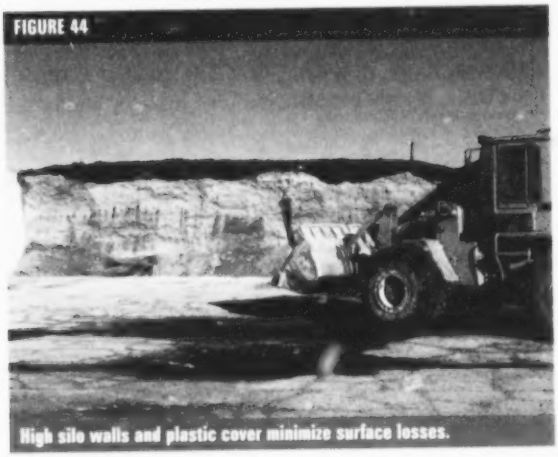
- harvest the crop at a higher moisture content
- reduce the length of cut so packing will be more effective – note that the sharpness of cutter bars can affect actual cutting length
- pack the silage more to exclude air

Continue to monitor silage moisture and temperature to determine the correct wilting time and length of cut. Per cent moisture is best determined with a microwave oven or a moisture tester (see the *Harvesting* chapter). Silage in storage should have a 60 to 70 per cent moisture content, but 65 per cent moisture is the best level to aim for. Silage temperatures can be monitored using long stemmed dial or digital thermometers, or with the hand, once experience has been gained.

### Covering horizontal silos

Covers prevent surface spoilage and prevent air from penetrating deep into the silage causing losses in the feed quality that are not obvious to the eye. As silage stacks and most bunkers have a large surface compared to the volume contained, covers are especially important to keep losses low. The spoiled silage on the surface of a 12- to 24-m (40- x 80-ft) silo is estimated to be worth six or more times the cost of a plastic cover (Figure 44).

**FIGURE 44**

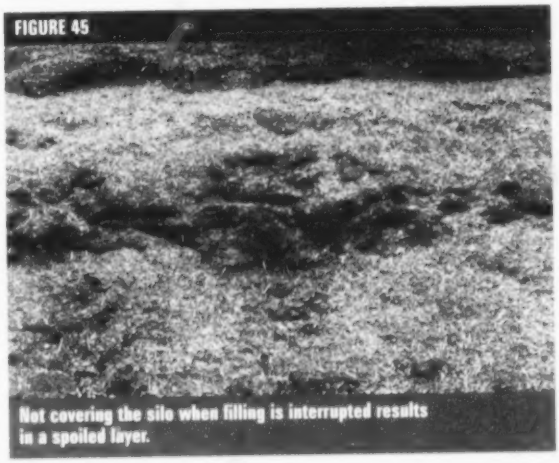


**High silo walls and plastic cover minimize surface losses.**

When the top surface of the silage has been properly packed, it should be covered immediately with 6 mil silage grade polyethylene or reinforced plastic to prevent fresh air or rainfall from entering the silage. Extend the cover forward often as the silo is filled. If there is an extended break in harvesting, the partially filled silo should be covered completely (Figure 45).

The plastic cover must be held in place so air cannot enter the silage. A continuous layer of used tires works well for this purpose (Figure 46). If the layer is not continuous, the plastic may blow in the wind and tear. Tires are easy to place as the plastic is spread out and easily removed as the silage is used. Straw bales or chopped silage may also be spread over the plastic. Another method is to use a fish net or twine

**FIGURE 45**



**Not covering the silo when filling is interrupted results in a spoiled layer.**

**FIGURE 46**

**A continuous layer of used tires works well to hold plastic covers in place.**

mesh to hold the plastic tightly over the silage. This cover stays tight after the silage shrinks, and it requires little labor to handle.

Seams and edges in the plastic cover must be sealed. A seal is made with a 46-cm (18-inch) overlap of the plastic sheets set into a groove in the silage surface. The seam is then covered with soil. The edges of a horizontal silo must be kept sealed since shrinkage leaves a space along the walls.

Tears in the cover must be repaired to preserve the seal. Plastic covers last only one year.

### Size and capacity of horizontal silos

The correct height and width to make a silo depends on daily silage usage, based on the removal of a minimum of 10 cm (4 in) per day from the silage face. Less usage than the minimum leads to spoilage or freezing problems. The silo should be as high as possible

to minimize the width, thereby minimizing spoilage from the surface (Figure 47). Silage height also helps in packing the silage. The height is limited by the reach of unloading equipment, the wall construction or to between 1.8 and 2.4 m (6 and 8 ft) if self-feeding off the face of the silage pit. A minimum width is 7.3 m (24 ft) for front-end loader work.

**FIGURE 47**

**The area of the silage face should permit the removal of 10 cm per day to minimize spoilage losses.**

Silo capacity depends on the type of crop, the moisture content, the length of cut and the amount of packing. Table 24 is based on barley silage with a dry density of 232 kg/m$^3$ (14.5 lb/ft$^3$) and a moisture content of 60 per cent (equivalent to a wet density of 580 kg/m$^3$ (36.2 lb/ft$^3$)).

Grass/legume silage typically has a dry density of about 255 kg/m$^3$ (15.9 lb/ft$^3$) (or a wet density of 638 kg/m$^3$ (39.8 lb/ft$^3$) at 60 per cent moisture content). Corn silage is about 260 kg/m$^3$ (16.2 lb/ft$^3$) (or a wet density of 650 kg/m$^3$ (40.6 lb/ft$^3$) at 60 per cent moisture content).

To convert capacities in Table 24 to:

- grass/legume silage at 60 per cent moisture content, multiply by 1.10
- corn silage at 60 per cent moisture content, multiply by 1.12
- any silage at 65 per cent moisture content, multiply by an additional 1.143
- any silage at 70 per cent moisture content, multiply by an additional 1.33

Example: In a silo 4 m (13.1 ft) deep, 20 m (65.6 ft) wide, and 50 m (164 ft) long, filled with grass/legume silage at 65 per cent moisture content, the silo capacity is:

2747 x 1.10 x 1.143 = 3,454 wet tonnes (3,799 tons)

**Conversion Factors**

kg/m$^3$ x 0.0624 = lb/ft$^3$
m x 3.28 = ft
tonnes x 1.1 = tons

The silo length depends on the total silage needed annually. Some horizontal silo capacities appear in Table 24.

Silo capacities can only be estimated because the amount of packing, dry matter content of the material, length of chop and silage material will affect the storage capacity of silage/haylage in all types of storage structures.

**TABLE 24**
**Estimated capacity of horizontal silos[1]**

| Wall height (m) | Silo width (m) | Silage per 10 cm (tonnes) | Silage per metre (tonnes) | Silo capacity (wet tonnes)[2] Silo length (m) 30 m | 40 m | 50 m | 60 m |
|---|---|---|---|---|---|---|---|
| 3.0 | 8.0 | 1.71 | 17.10 | 456 | 627 | 798 | 969 |
| | 12.0 | 2.65 | 26.50 | 702 | 968 | 1,233 | 1,498 |
| | 16.0 | 3.69 | 36.90 | 972 | 1,340 | 1,709 | 2,078 |
| | 20.0 | 4.82 | 48.20 | 1,263 | 1,745 | 2,226 | 2,708 |
| 4.0 | 12.0 | 3.44 | 34.40 | 877 | 1,221 | 1,566 | 1,910 |
| | 16.0 | 4.72 | 47.20 | 1,193 | 1,665 | 2,137 | 2,608 |
| | 20.0 | 6.08 | 60.80 | 1,531 | 2,139 | 2,747 | 3,355 |
| | 24.0 | 7.54 | 75.40 | 1,888 | 2,642 | 3,396 | 4,149 |
| 5.0 | 16.0 | 5.77 | 57.70 | 1,400 | 1,977 | 2,554 | 3,131 |
| | 20.0 | 7.37 | 73.70 | 1,778 | 2,515 | 3,252 | 3,989 |
| | 24.0 | 9.06 | 90.60 | 2,175 | 3,081 | 3,988 | 4,894 |
| | 28.0 | 10.85 | 108.50 | 2,590 | 3,675 | 4,760 | 5,845 |

[1] Based on barley silage with dry density of 232 kg/m$^3$ and 60% moisture content.
[2] Capacity is calculated based on the following assumptions: the side slopes and the one end slope are at 5:1; the front has a 2:1 slope; and the heap slope is 1:5.

## Large bale silage

Various methods can be used for storage of large bale silage.

### Trench silo

In this method, big round or square bales are stacked as tightly and as evenly as possible into a trench. The bales are usually stacked three bales high. The trench should have a gravel or sand floor. Walls that slope outward make stacking easier. A packing tractor is used on the top to exclude air. Uniform placing of bales and careful use of a suitable tractor, such as a four-wheel drive tractor with duals, are required to do this.

The top is sealed with plastic similar to that used with chopped silage. It is advantageous to line the walls with plastic since bales do not form as tight a seal as cut silage.

### Plastic bags — individual bales

In this method, each bale is individually bagged (Figure 48). Bags are available in sizes to fit various bale chamber widths. A 1.2-m (4-ft) diameter size is common. This size also accommodates a 1.1-m x 1.1-m (3.5-ft x 3.5-ft) square bale. Six mil plastic is recommended.

FIGURE 48

Individual bales can be wrapped or bagged

It is a demanding task to put bales into bags. They may be lifted with a front loader, so the bag can be pulled on from the bottom. A single tooth prong on the front loader is forced into the center of the bale to lift it, and then the bag is slid on by hand from the end.

Excluding oxygen is difficult since the bale contains air, and the bag usually does not fit tightly. Piling the bagged bales before sealing the bag ends helps squeeze the air out. Both ends of the bag should be double tied to seal them after piling. It is difficult to prevent tearing or puncturing bags during filling and piling. Holes must be patched.

Bales should be placed on a well-drained site. A sand floor is preferred. Outside stacks should be covered. Keep the storage area free of vegetation and other stored feed, and bait the area for rodent control to reduce the chance of rodents gnawing holes in the plastic bags.

### Plastic bags — multiple bales

Bagging machines have been developed to package up to 22 bales in 30-m (100-ft) plastic tubes (Figure 49). The process and management are similar to that for individual bags. This system requires a higher capital outlay. The tubes can only be used once.

FIGURE 49

Bagging machines can package multiple bales

### Plastic wrap

Individual round bales can be wrapped with thin plastic film, using a machine that "tumbles" the bale inside the rolls of plastic (Figure 50). Careful operation is required to ensure a complete seal.

FIGURE 50

Continuous wrapped bale silage

### Plastic-covered bale stacks

In this system, large bales are piled and covered with 6 mil polyethylene or reinforced plastic. A 12-m x 30-m (40-ft x 100-ft) sheet of polyethylene without joints works well. Reinforced plastic makes a superior cover since it does not stretch or tear easily. Anchored fish net or twine is needed to keep the cover tight. The cover must be sealed around the perimeter of the stack.

This system works very well for large square bales. However, for large round bales, it is virtually impossible to adequately exclude air from the silage.

Ideally each sealed unit should contain no more than a week's supply. The bales generally have a shelf life of one week once the seal is broken.

## Bagged silage – continuous tubes

Polyethylene bags (Figure 51), called silo bags, provide low capital cost storage for silage. They can be used alone or as additional storage in combination with another system. Forage is chopped and compacted into a plastic tube with a bagging machine. A moisture content of 60 to 65 per cent is recommended, although somewhat drier forage is also satisfactory.

**FIGURE 51**

Silage bags (continuous tubes)

Bagging machines exclude air in the process of stuffing forage into the bags. The silage bags are oxygen-limiting systems, although the plastic is not 100 per cent impermeable to oxygen. Any tears or holes in the bags should be mended as soon as possible. Bags should be used only once.

Silage bags are most satisfactory for short-term storage. After filling, silage should be used before the next summer (for more information, see P.H. Robinson et al., 1987). Manufacturers' instructions for bagging machines and bags should be followed closely to achieve good results.

**Bag capacity:** As with bunker silos, bag capacities depend on the type of crop, the moisture content, the length of cut and the amount of packing. The amount of packing appears to be a function of the machine type and the operator. According to a study by Muck and Holmes (2001), typical dry matter (DM) density of legume silage at 60 per cent moisture content was about 202 kg/m$^3$ (12.6 lb/ft$^3$) or 505 kg/m$^3$ on a wet basis (31.5 lb/ft$^3$). Typical DM density of corn silage at 60 per cent moisture content was about 220 kg/m$^3$ (13.7 lb/ft$^3$) or 550 kg/m$^3$ wet (34.3 lb/ft$^3$). Assuming the DM density of cereal silage is in the same relative proportion as in bunker silos, the DM density of cereal silage at 60 per cent moisture content should be about 193 kg/m$^3$ (12.0 lb/ft$^3$) or 483 kg/m$^3$ wet (30.1 lb/ft$^3$). Table 25 gives some approximate capacities of several sizes of bags, based on 1-m length increments.

**Bag storage site:** The bags should be located close to the feeding area since they cannot be moved once they are filled. The storage site should be well drained and level if possible. If the bags must be located on a slope, the bags should be started at the top and proceed downslope. The storage area should be free of rocks and debris that could puncture bags. It should also be free of vegetation and other stored feed to discourage rodents from inhabiting the area and gnawing holes in the bags. Baiting for rodent control may be necessary. The area should be fenced from livestock and be sheltered from wind to minimize snow drifting problems.

**TABLE 25**
**Estimated capacity of silage bags (continuous tubes)**

| Bag diameter (m) | Cereal silage* (wet tonnes/m of length) | Legume silage* (wet tonnes/m of length) | Corn silage* (wet tonnes/m of length) |
|---|---|---|---|
| 2.4 | 2.18 | 2.28 | 2.49 |
| 2.7 | 2.84 | 2.98 | 3.24 |
| 3.0 | 3.41 | 3.57 | 3.89 |

* At 60% moisture content. To convert capacities for silage at 65% moisture content, multiply these values by 1.143.
Source: Muck and Holmes (2001).

## Tower silos

Tower or vertical silos are the most adaptable to mechanized feed handling. This silo type fits best where livestock herds are densely confined and mechanical feed bunks are the preferred feeding system.

Tower silo silage systems are the least affected by weather conditions. Storage losses are generally lower and less variable than with other systems because of the better oxygen exclusion, and this may be an advantage when high quality feed is required, such as for dairy herds.

As initial construction costs are high, tower silos are most suitable where 2,000 tonnes (tons) capacity or less is required.

### Foundation footings for tower silos

The soil under the silo foundation and the foundation itself must be capable of supporting the silo and its contents. The footing must be designed for the size of silo, both diameter and height, and the type of soil on which it is placed. The footing must be designed to carry the weight of the silo wall itself and two-thirds of the weight of the stored silage. The height of the silo should be less than four times its diameter and the settled silage height only three to three and one-half times its diameter.

The soil must support the loaded silo without movement (Figure 52). A footing must have enough bottom surface area to distribute the silo and silage loads to the soil and still keep the soil pressure less than its maximum load-carrying capacity. Expect some variation in size and type of footings and a resulting variation in cost for different silos, depending on the soil type.

FIGURE 52

The soil under the silo foundation and the foundation itself must be capable of supporting the silo and its contents.

Because the structural adequacy of a silo is so dependent on the construction of a proper footing, for the buyer's protection, the silo contractor should be required to build and guarantee the footings. At the very least, the contractor should provide detailed plans and specifications for the construction of the footings based on the soil type, and should be prepared to accept responsibility for the whole silo, not just the part above the ground.

If in doubt, the purchaser should hire a soils consulting engineer to test the soil and design the footing. Lack of an adequate foundation and poor soil drainage have caused several tower silos to topple.

### Pre-cast concrete stave silos

These silos (Figure 53) have the potential advantage of excellent quality of construction at the manufacturing plant. They have relatively thin walls but the strength of the concrete is high. Pre-cast concrete stave silos can be erected quickly. The final quality of the silo depends on proper construction on the farm. An interior coating is needed to reduce the corrosive effect of silage acids.

FIGURE 53

Concrete stave silo

Proper maintenance is very important. Adjustable steel hoops on the outside of the silo require the correct tensioning. These need to be re-adjusted after the silo has been used for one season. There is a potential for air leaks through the many joins between staves. These joins are usually filled with the interior coating in the silo.

FIGURE 54

Cast-in-place concrete silo

### Cast-in-place concrete silos

Cast-in-place concrete silos (Figure 54) have relatively thick walls (compared to pre-cast types) and are structurally more suitable for large, and especially for high, silos. Critical strength is less affected by silage acid attack. There is less potential for air leaks, although construction joints may leak and should be sealed.

### Concrete tower silo preservation and repair

The corrosive effect of silage acids on concrete and metal fixtures is a major problem with all upright concrete silos. The greatest corrosion occurs on the bottom quarter of the silo, especially the bottom 3.7 m (12 ft). Corrosion is especially hazardous with tall silos since there is greater silage compaction causing increased seepage near the bottom. The need for high concrete strength is obvious. If seepage is a concern after one filling cycle, lower moisture silage may be used during initial filling the next time the silo is used. Adequate moisture for good silage making still takes priority over seepage prevention.

High quality concrete is used in silo wall construction. It provides the necessary strength and a certain level of resistance to silage acid attack. Additives may be included in the concrete mix to improve the protection from acid corrosion of the silo wall. Acid-resisting coatings may be applied to the silo wall interior to add more protection. Coatings must be applied according to the supplier's directions. The use of concrete additives and wall coatings may be discussed with the silo contractor during the silo design phase.

Coatings may also be applied to existing silos provided the interior wall is adequately cleaned and prepared.

FIGURE 55

Oxygen-limiting silo

### Oxygen-limiting silos

These silos (Figure 55) have airtight walls, floor and roof and an apparatus to stop entry of air into the silo. They provide maximum control of in-storage atmosphere but have a high initial cost. They operate well at a wide range of silo diameters. Oxygen-limiting silos require periodic checking to ensure they remain airtight and that pressure relief valves and bags are operating correctly.

Moisture content of the silage should be 40 to 50 per cent. Oxygen-limiting silos provide the highest potential for proper ensiling with minimum spoilage provided the silo has no air leaks. Bottom unloading permits continuous feeding with no sudden change in the ensilage while refilling the silo. Cost per tonne (ton) of silage stored depends on the number of times the silo is refilled each year. There is no minimum silage removal rate since the silo remains sealed.

Glass-lined steel silos have the potential for long life provided the seal is maintained between all component sheets. These silos may be extended in height if planned for at the time of initial construction. They may also be taken down and rebuilt at another location.

### Filling a tower silo

The forage blower used to elevate the silage into the silo must be capable of blowing to the required height and at a capacity to match the output of the field harvesting system. Feeder boxes improve the blower capacity by allowing it to run a larger portion of the time. With proper adjustment of fan blade clearance, 22.7 t/h (25 tons/h) can be blown with a tractor with a PTO rating of 41 kW (55 hp). Another estimate of blower tractor power is 2.5 kW/m (1 hp/ft) of silo height. Uniform feeding to prevent overloading the blower helps avoid plugging. A small amount of water added at the blower helps keep legume crops or drier silage from sticking to the blower pipe.

Continuous loading and uniform distribution in the silo help produce the correct conditions for the ensiling process. The weight of the new silage added packs the silage in the silo. As the silo is filled closer to capacity, the settling of the silage becomes more noticeable. More silage can usually be added after one or two days of settling.

To prevent seepage in silos over 24 m (80 ft) tall, silage should be maintained at 65 per cent or lower moisture content. To reduce winter freezing problems, keep the moisture content below 65 per cent in concrete tower silos and below 50 per cent in oxygen-limiting silos.

### Tower sizing and capacity

**Concrete silos:** The diameter of a concrete tower silo is determined by the amount of feed needed to remove at least 5 to 8 cm (2 to 3 in) of silage daily. The larger the diameter of a silo, the lower the storage cost per ton. The height of the silo is determined by the amount of silage needed for the feeding period.

**Oxygen-limiting silos:** The maximum amount of silage to be stored at one time determines the size of an oxygen-limiting silo since there is no minimum removal rate. The height to diameter ratio should not exceed four.

Silo capacities can only be estimated since moisture content, length of cut, crop used and friction of the silo wall all affect the density of the settled silage. Silage density also varies with silage depth. For example, silage at 70 per cent moisture content might be 685 kg/m$^3$ (42.7 lb/ft$^3$) at 10 m (32.8 ft) deep, but will increase to about 1,015 kg/m$^3$ (63.3 lb/ft$^3$) at 24 m (78.7 ft) deep. Similarly, silage at 45 per cent moisture might be 374 kg/m$^3$ (23.3 lb/ft$^3$) at 10 m deep, but will increase to about 554 kg/m$^3$ (34.6 lb/ft$^3$) at 24 m deep.

**TABLE 26**
**Estimated epoxy-coated concrete and glass-lined steel silo capacities for forages***

| Silo diameter x settled depth (m) | (ft) | Cereal silage(tonne) | | Alfalfa silage(tonne) | | | Corn silage(tonne) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 60% M.C. | 70%M.C. | 40% M.C. | 50% M.C. | 60% M.C. | 60% M.C. | 65% M.C. | 70% M.C. |
| 6.1 x 21.3 | 20 x 70 | 423 | 607 | 300 | 374 | 430 | 419 | 471 | 540 |
| 6.1 x 24.4 | 20 x 80 | 496 | 709 | 354 | 441 | 576 | 487 | 547 | 625 |
| 7.3 x 18.3 | 24 x 60 | 531 | 756 | 368 | 459 | 600 | 512 | 577 | 662 |
| 7.3 x 21.3 | 24 x 70 | 640 | 908 | 449 | 568 | 727 | 611 | 686 | 784 |
| 7.3 x 24.4 | 24 x 80 | 751 | 1,062 | 532 | 660 | 857 | 710 | 795 | 907 |
| 7.3 x 27.4 | 24 x 90 | 863 | 1,217 | 616 | 764 | 988 | 809 | 905 | 1,031 |
| 9.1 x 24.4 | 30 x 80 | 1,232 | 1,722 | 867 | 1,070 | 1,379 | 1,269 | 1,453 | 1,606 |
| 9.1 x 27.4 | 30 x 90 | 1,419 | 1,975 | 1,007 | 1,240 | 1,590 | 1,472 | 1,690 | 1,860 |
| 9.1 x 30.5 | 30 x 100 | 1,607 | 2,229 | 1,150 | 1,411 | 1,803 | 1,678 | 1,923 | 2,116 |
| 9.1 x 33.5 | 30 x 110 | 1,796 | 2,483 | 1,294 | 1,584 | 2,017 | 1,886 | 2,159 | 2,374 |

* The capacity in tons (2000 lb) can be obtained by multiplying the capacities in the table by 1.1
M.C. = moisture content
Source: Alfalfa and corn information adapted from Ontario Ministry of Agriculture and Food Agdex 100/732

Table 26 shows estimates of epoxy-coated concrete and glass-lined steel tower silo capacities for cereal, alfalfa and corn silage. Capacities for grass silage may be estimated from Table 26 by increasing the alfalfa silage capacity by 10 per cent for 50 per cent moisture, and by 15 per cent for 60 per cent moisture. The capacity of concrete tower silos without epoxy-coated walls is less because of the increased friction between the wall of the silo and the silage.

## FEEDING SILAGE

The choice of silo type is affected by the feeding system or method that is best for the farm. The type of feeding system depends on:

- the degree of freedom of movement of the livestock herd
- the labor input to the feeding operation
- the volume and timing of the feeding program
- the type of livestock operation

For example, most dairy confinement operators prefer a tower silo located close to the barn. This system is fully automated to convey silage directly from the silo to the feeder in the barn. The milking herd does not have to move from the confinement area. There is little waste in the mechanical conveyor system. The silo unloader must be checked regularly to ensure proper cutting adjustment, particularly in winter. The unloader may have to cut some frozen silage from the silo wall. Silage with a slightly lower moisture content will reduce downtime of silo unloaders.

In large feedlots, silage is usually distributed to the feed bunks (Figure 56) with a mixer feed truck or a feed wagon. Loading the silage from a trench or bunker silo is quickest with a front-end loader (Figure 57). The loader scrapes a slice from the silage face and loads the silage into a mixer feed truck or wagon. If a limited amount of silage is removed, a bunker silo unloader may be used. This unloader has a cutting head that leaves a more cleanly shaven silage face to minimize spoilage.

Operators who feed smaller groups of livestock have more flexibility and a wider choice of silos. With a reasonable amount of care and attention, losses of silage between the silo and the animal should be less than 4 per cent (Figure 58).

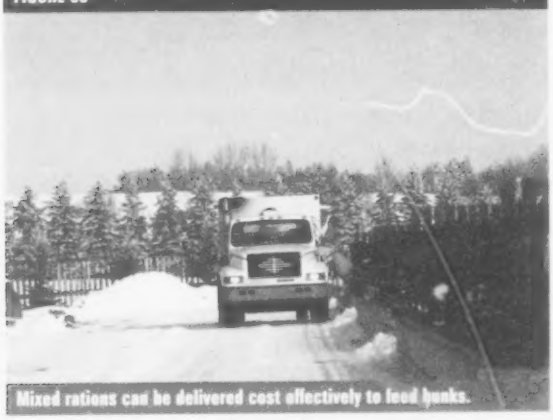
**FIGURE 56**

Feeding silage on a fenceline feeder.

**FIGURE 57**

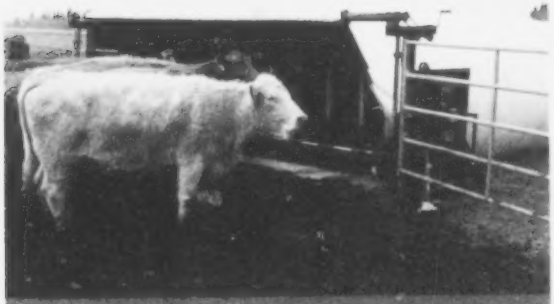
Front-end loaders are quick for loading silage, but care must be taken to scrape silage evenly from the silage face to minimize spoilage.

**FIGURE 58**



Mixed rations can be delivered cost effectively to feed bunks.

**FIGURE 59**



Self-feeding can reduce machinery costs.

With small livestock operations, self-feeding of silage is sometimes used to reduce machinery operating costs (Figure 59). For self-feeding, cattle require a 25-cm (10-in) width of feeding space per head. Maximum silo height is 2.4 m (8 ft). In winter, at least 10 cm (4 in) should be consumed from the face of the silo each day to minimize losses, and in summer, at least 15 cm (6 in) should be consumed. Based on 50 head consuming 34 kg (75 lb) of 65 per cent moisture silage per day, a silo that is 12 m (40 ft) wide and 2.4 m (8 ft) high would have 10 cm (4 in) removed each day. However, summer use would reduce silo height by one-third to remove 15 cm (6 in) of silage off the face.

Limit feeding in winter would reduce the height by about half since more feeding space is required per head. The decreased height means there is greater surface area relative to silo capacity, that is, surface spoilage losses are a greater percentage of the total. Self-feeding often results in losses due to animals trampling and wasting feed. Systems based on self-feeding should be used with an understanding of the limitations of this feeding method.

Alberta Agriculture, Food and Rural Development agricultural engineering staff can help producers to plan their silage storage and feeding systems. The overall system plan is very important to a successful silage operation.

## SAFETY IN SILAGE MAKING AND STORAGE

A well-managed silage operation will normally avoid the circumstances that set the stage for an accident to occur. However, problems occasionally arise during harvesting, ensiling or feeding. To avoid accidents, the motto must always be "safety first." Always take time to anticipate and prevent the potential for injury and life-threatening situations.

### Machinery operation

Silage cutters and blowers have parts that continue to rotate after the power-take off has stopped. Only when the tractor power is shut off and the machinery has stopped spinning can the operator check the sharpness of cutter knives or clear plugged material.

In horizontal silos, the surface of silage being packed by a tractor is soft and unstable. The silage next to a bunker wall and the sides of silage stacks are particularly prone to giving way under the tractor's weight. Steep slopes or digging the drive wheels into silage can lead to backward overturn. The packing tractor should have a rollover protection cab, and the operator should "buckle up."

### Silo gas

Silo gas has claimed many lives. Always assume that both $CO_2$ (carbon dioxide), which can asphyxiate a human, and $NO_2$ (nitrogen dioxide), which is poisonous, are present in a tower silo. In one survey, 42 per cent of all silos tested contained $NO_2$ concentrations high enough to be considered hazardous to human health.

Therefore, always take precautions before entering an upright silo, including:

- running the blower for at least 10 minutes to circulate the air (the blower is more effective as a silo ventilator if it is run with all the chute doors closed and the roof panel open)
- wearing a proper breathing apparatus
- wearing a safety harness and having at least two extra men on hand to pull you out in case you fall

Other safety practices include:

- posting a warning sign in an obvious place, such as beside the silo chute
- ventilating the feed room if the silo chute connects directly to the feed room
- watching for silo gas indicators (for example, dead flies or mice on the feed room floor, unnatural breathing of livestock or people, an acrid bleach-like odor or a brownish haze)

For more information on safety procedures, see Canada Plan Service's *Silo Gas* brochure (available at http://www.cps.gov.on.ca/english/gs7000/grain.htm).

When nitrates are degraded in the ensiling process, nitrogen oxides are formed as products of microbial metabolism. The $NO_2$ that results when nitrogen monoxide contacts air is often called silo gas. It is highly toxic to man and animals when present in concentrations greater than 10 to 25 ppm. Pulmonary edema occurs when the gas combines with water in the lining of the respiratory tract, and this combination can cause pneumonia-like symptoms and death. Even if the gas does not cause death, respiratory tract damage can occur. Relapses are common after apparent recovery.

Extreme caution is necessary to avoid this toxic silo gas. Vents should be opened carefully. Posted warnings can help lower the risk of exposure (Figure 60). All family members, visitors and employees should be warned about the potential danger.

Since $NO_2$ is heavier than air, the brown gas is sometimes clearly visible inside silos, around silo openings and in silage bags. Most of the $NO_2$ is evolved from the silage in the first week of fermentation, with production peaking at two to three days after ensiling. There is essentially no $NO_2$ production after the material has been in the silo for more than 10 days.

**FIGURE 60**

CAUTION TOXIC
GASES PRODUCED DURING THE FERMENTATION PROCESS ARE TOXIC. USERS SHOULD USE EXTREME CARE IF BAG IS OPENED OR PUNCTURED DURING FERMENTATION PERIOD.

**Vents for silo gas should be opened carefully to avoid any exposure to the escaping gas. Posted warnings can lower the exposure risk and are recommended.**

# Chapter 6: **Evaluating Silage Quality**

Silage quality is a big concern for producers. Because the quality of feed coming out of the silage system cannot be any better than the quality of the feed going in, producers should take samples for laboratory analysis both before and after the forage is ensiled. Specific sampling techniques should be followed.

## FORAGE QUALITY

Ensiling does not improve the quality of a forage. The quality of the feed taken out of the silo can be no better than the quality of the feed that was put into the silo.

## SAMPLING FOR QUALITY ANALYSIS

It is extremely important that a representative sample of silage be obtained for quality determinations. The usefulness of the analysis is determined in large measure by how well the sample taken represents the silage as a whole. It is of little value to do quality evaluation of a silage sample that does not represent the silage being fed.

### Fresh forage samples

Forage samples for analysis should be taken as the silo is being filled. Sample each field and crop type separately. Take small samples of each load brought to the silo. As soon as possible after a load is sampled, the sample should be placed in an airtight container and stored in a cool place such as a refrigerator or freezer. Individual samples from one field or crop type should be well mixed and a subsample taken for laboratory analysis. Enough forage to fill a container the size of a bread bag is more than adequate for lab analysis. The container should be sealed to avoid moisture loss and frozen until it is submitted or mailed to a laboratory.

Fresh forage samples reflect the quality of the forage before ensiling. They may not reflect the final quality of the ensiled product. If the ensiling process was subject to such negative factors as a delay in covering, air leakage or seepage, the final silage may differ greatly in quality from the forage that went in.

### Ensiled samples

Analysis of the ensiled product is key to developing a balanced feeding program. Comparison of the analysis results for the ensiled sample with the results for the fresh forage sample can be a great learning tool for determining how effective the ensiling conditions were.

There are several options for collecting samples of the ensiled product. One is to do the sampling as the silage is being removed from the silo. Take individual samples from as many sites as possible from the face of the exposed silage as soon as possible after the surface of the silage is exposed. Then mix the samples together into one sample for analysis.

Another option, which has great merit, is to use a five-foot silage probe. For silage piles, probe the top of the pile in four or five locations and then tape the holes in the plastic. For bale silage, probe 10 to 15 bales and then patch the holes in the plastic. For either system, mix the collected samples together, and submit a sample of the mixture to the lab for analysis.

Using a silage probe has two benefits: it allows a feed analysis prior to the silage being opened, and it tests the quality of the silage after all the variables of the ensiling process are complete. This sample method is the most accurate one for assessing the quality of the final product.

When sampling upright silos, combine individual samples taken over several days. Store the individual samples in an airtight container in a refrigerator or freezer until you are ready to mix them together and send a sample to the lab.

For ensiled samples, like fresh forage samples, subsamples should be mixed thoroughly and then a sample of the mixture should be sent to the lab. The sample size should be about the amount of silage that would fill a bread bag. Samples should be placed in airtight containers and frozen until sent to the laboratory.

### Shipping

Avoid shipping or mailing samples at times when mail delivery may be delayed, such as close to weekends or holidays, because fresh forage samples deteriorate rapidly under warm conditions. Send the forage samples to the laboratory near harvest time rather than waiting until just before feeding or until other samples are

available. All laboratories receive very large increases in samples numbers in the fall and early winter, which may result in delays if you submit your samples during that period.

## VISUAL EVALUATION

By itself, visual examination will not provide accurate information on nutrient content of silage. However, coupled with a chemical analysis, factors such as color, odor and general appearance provide a good indication of the expected overall nutritive value. Chemical and visual characteristics that relate to nutritive value in grass and legume forages are listed in Table 27. Figures 61 to 66 show examples of good quality silage made from various crop types.

**GOOD QUALITY SILAGE**

FIGURE 61

Barley

FIGURE 62

Alfalfa and timothy

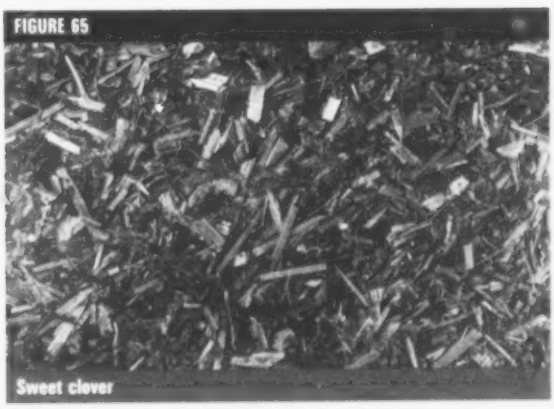
FIGURE 63

Wheat and peas

FIGURE 64

Red clover

FIGURE 65



Sweet clover

FIGURE 66

Corn

The effect of the microbiological process on the forage during ensiling needs to be evaluated, since even if the original material was of good quality, the material may have ensiled poorly. Table 28 provides some guidelines for assessing this aspect of silage quality.

**TABLE 27**
**Chemical and visual characteristics of grasses and legumes in relation to forage quality**

| Quality | Stage of maturity | Protein(%) | ADF*(%) | Description |
|---|---|---|---|---|
| Excellent | Prebloom legumes | 19 | under 31 | 40-50% leaves, less than 5% foreign material such as straw and weeds |
| Very Good | Early bloom legumes | 17 - 19 | under 34 | 35-45% leaves in legumes, more than 50% leaves in grasses, less than 5-10% foreign material |
| Good | 50% or more of legumes in bloom; boot to head stage in grasses | 12 - 17 | under 39 | 25-40% leaves in legumes,more than 40% leaves in grasses, less than 15% foreign material |
| Fair | Full bloom in legumes, grasses in head to milk stage | 8 - 12 | over 39 | Less than 30% leaves in legumes, grasses 30-40% leaves, or more than 10-15% foreign material |
| Poor | Legumes past full bloom, grasses in dough to seed stage | under 8 | over 42 | More than 20% foreign matter in legumes, very mature forage, few leaves, etc. |

*ADF – acid detergent fibre is a measure of the cellulose, lignin and cutin content of forages.
Source: Modified from Rohweder et al. (1978).

**TABLE 28**
**Visual and pH evaluations of silage**

| Characteristic | Good quality | Intermediate quality | Poor quality | |
|---|---|---|---|---|
| | | | Poorly fermented | Overheated |
| **Silage characteristics** | | | | |
| Color | Bright, light green yellow or green brown depending upon material ensiled | Yellowish green to brown green | Very dark green, blue green, grey or brown | Brown to black |
| Smell | Lactic acid[3] odor with no 'butyric acid'[4] odor | Slight butyric acid and 'ammonia'[5] odor | Strong butyric acid, ammonia odor rancid | Burnt sugar or tobacco smell |
| Texture | Firm, with softer material not easily rubbed from fibre | Softer material can be separated from fibre | Slimy, soft tissues easily rubbed from fibre, mouldy | Dry, easily broken down when rubbed, mouldy |
| Moisture[1] | 60-70% horizontal silos 60-65% concrete towers 40-50% oxygen limiting silos | Tends to be above 65% | Usually over 72% | Usually less than 55% Depends on type of structure |
| pH[2] | Below 4.2 for wet crops below 4.8 for wilted silages | 4.6 to 5.2 | Over 5.2 | pH is not a reliable guide |
| **Causes and remedies** | | | | |
| Cause | N/A | Too much moisture, not enough plant sugars | Too much moisture and insufficient plant sugars | Too little moisture. Poor packing. Poor sealing Length of cut too long, slow silo filling |
| Remedy | N/A | Poor fermentation may be corrected by ensiling at a lower moisture, using preservatives or sealing silo | Wilt in field or use chemical and/or microbiological additives, seal silo quickly | Pack silage to exclude air, chop finer to facilitate packing, seal silage, ensile at a higher moisture. Fill silo rapidly and cover if delayed. |

[1] See *Harvesting* chapter for methods for estimating moisture content of silage.
[2] pH can be determined with litmus paper which can be obtained from a pharmacist or with a pH meter.
[3] Lactic acid odor is similar to that of sour milk.
[4] Butyric acid odor is similar to that of rancid butter or fat, putrid.
[5] Ammonia odor is similar to that of some household cleansers or anhydrous ammonia.

## CHEMICAL ANALYSES

Although silage quality can be estimated by visually examining the silage, it can only be measured accurately by chemical analysis.

The most important analyses obtained from feed testing laboratories include dry matter (moisture content is calculated as 100 minus per cent of dry matter), pH, crude protein content, fibre, calcium and phosphorus. Analyses for other nutrients are also available.

Feed test reports can be evaluated in the same way for silages as for other forages. However, if the silage has heated too much, the digestibility of protein and dry matter may be greatly reduced. If temperatures in excess of 40°C have occurred, as evidenced by a charred appearance or tobacco-like odor, it is useful to have the laboratory perform an acid detergent insoluble nitrogen (ADIN) analysis. In general, if the ADIN content of a material is above 0.3 per cent of the dry matter or 15 per cent of the total nitrogen in the forage, it indicates that excessive heating has occurred and that the feed value has been reduced (see Table 29). If this is the case, check with a nutritionist on options to balance the feed for good nutrition.

### Silage pH as an indicator of quality

The best single indicator of the effect of ensiling on the nutritive value of high moisture silage is pH. The relationship between pH and silage quality can be determined from Table 29. In general, the lower the pH, the better, because a low pH indicates that a lactic acid type of fermentation has occurred. However, pH is not an accurate indicator of quality for silage that contains less than 65 per cent water or silage that has long particle length, such as bale silage.

The pH level is used to gauge the success of the ensiling process, as well as the stability of the silage. A low pH indicates that all factors through the ensiling process were acceptable, including moisture, water-soluble carbohydrate concentration, packing density and covering. A low pH also indicates stability through the feed-out process. Low pH silage will have a lower risk of freezing, regardless of moisture; less deterioration and heating after the silage is uncovered; and less spoilage in the feed bunk. Therefore, every effort must be made to ensure a low pH, and all feed analyses should include pH testing.

### Fermentation products in silage

Normally, commercial laboratories do not determine the concentrations of acids or ammonia in silage. However, if this information is available, it is very useful. Table 29 lists the concentrations of acids and ammonia for different qualities of silage.

**TABLE 29**
**Fermentation products and silage quality in dry matter**

| Characteristic | Silage quality | | |
|---|---|---|---|
| | Good | Intermediate | Poor |
| pH of silages with under 65% moisture | under 4.8 | under 5.2 | over 5.2 |
| pH of silages with over 65% moisture | under 4.2 | under 4.5 | over 4.8 |
| Lactic acid (%) | 3 - 14 | variable | variable |
| Butyric acid (%) | under 0.2 | 0.2 - 0.5 | over 0.5 |
| Proportion of total acids (%) | | | |
| Lactic | over 60 | 40 - 60 | under 40 |
| Acetic | under 25 | 25 - 40 | over 40 |
| Butyric | under 5 | 5 - 10 | over 10 |
| Ammonia N (% of total nitrogen) | under 10 | 10 - 15 | over 15 |
| ADIN (% of total nitrogen) | under 15 | 15 - 30 | over 30 |

# Chapter 7: **Feeding Value of Silages**

Silage provides nutritious livestock feed. If the silage system is effective, nutrient levels can be similar to that of the standing forage crop. Nutrient content will vary with the crop and the moisture content. Palatability is also a concern, and producers need to be aware of factors such as length of chop, animal performance issues and special problems.

## NUTRIENT CONTENT OF HAYS AND SILAGES

Ensiling is an effective method of preserving feed with a minimum of nutrient loss. If ensiled properly, the nutritive value is similar to that of the standing forage crop. Since fewer field losses occur when forage is ensiled than when it is put up as hay, material for ensiling often contains more nutrients than hay. However, there is a slight loss in quality during the ensiling process because plant sugars are degraded and proteins are broken down.

The ultimate comparison between hay and silage is thus influenced by the weathering and leaf losses that occurred during the haying process and the type of fermentation that existed during the ensiling process. In general, however, when rains are expected during the forage harvesting period, more nutrients are conserved with silage than with hay.

Chemically, fresh forage and silage differ greatly in two ways. First, silage contains fewer water-soluble carbohydrates than fresh forage since these are used in the production of organic acids in the ensiling process. These organic acids do not have a large effect on the nutritional value of the material since they are produced in the rumen of the animal in varying amounts in any case.

Second, considerable amounts of forage protein are degraded to non-protein nitrogen compounds such as amino acids, amines and ammonia in the ensiling process. Protein degradation products in silage are not as nutritionally useful as intact proteins in most feeding circumstances, and amines in particular may cause adverse reactions and a lower feed intake in animals.

Generally, the digestible energy content of silage is quite similar to that of the forage from which it was made, if the ensiling process was efficient. Prolonged aerobic conditions, due to poor management during filling and covering, can result in a reduction of digestible energy.

Although the crude protein of silage is similar to that of the original forage, 10 per cent or more of the protein in the forage will have been degraded to non-protein nitrogen.

The mineral content of silages is as high as in the original forage unless measurable amounts of seepage have occurred. Silage made from green forage at the proper stage of maturity and without excessive heating in the silo can be a good source of vitamin A for animals. Since sunlight is necessary for the formation of vitamin D in forages after cutting, silage that has been left in the field for only a short time will contain little vitamin D.

The nutrient contents of common ensiled forage crops grown in Alberta are given in Table 30. All values are on a moisture-free basis. Both the average level of the specified nutrient and the range of values one might expect are listed. As can be seen, the amount of any nutrient present in a feed is extremely variable. For this reason, feed testing is recommended.

## LENGTH OF CHOP AND ANIMAL PERFORMANCE

Particle length, as dictated by chop length, is documented to affect animal performance. As noted in the *Harvesting* chapter, the chop length affects packing density. For most crops, the average actual length of cut should be about 12 mm (0.5 in). Corn silage should usually be 5 to 12 mm (0.25 to 0.5 in) long for best packing and fermentation.

Some operators strive for finer chop silage, often shorter than 5 mm (0.25 in). This fine silage can have negative effects on animal performance. Several researchers have found a decrease in chewing activity. For example, Soita et al. (2000) found a decrease of 90 minutes for chop lengths of 4.7 mm, and Sudweeks et al. (1975) found a reduction of 30 per cent for chop lengths of 6 mm.

These trials concluded that particle length, and not neutral detergent fibre (NDF), has the dominant control over chewing activity. Decreased chewing activity results in decreased saliva production. Saliva is the principle means the cow has for buffering the acids produced during ruminal fermentation. Thus, reduced chewing activity reduces forage utilization and feed efficiency. In the study by Soita et al. (2000), the short particle length decreased milk yield and milk fat in dairy cows.

**TABLE 30**

**Nutrient analyses of selected Alberta-grown forages conserved as silage**

| Crop | Number of samples | | Moisture (%) | Protein (%) | Fibre (ADF)(%) | Calcium (%) | Phosphorus (%) |
|---|---|---|---|---|---|---|---|
| Alfalfa | 398 | Average | 55.4 | 18.2 | 36.1 | 1.77 | 0.25 |
| | | Range | 30.3 - 86.7 | 10.6 - 25.7 | 21.9 - 51.6 | 1.02 - 2.86 | 0.15 - 0.40 |
| Alfalfa/grass | 465 | Average | 56.8 | 14.6 | 37.8 | 1.32 | 0.23 |
| | | Range | 30.3-79.2 | 6.6 - 23.3 | 24.7 - 54.3 | 0.28 - 2.67 | 0.12 - 0.38 |
| Barley | 699 | Average | 63.2 | 11.1 | 32.8 | 0.46 | 0.26 |
| | | Range | 37.8 - 87.6 | 4.3 - 18.8 | 8.5 - 48.5 | 0.08 - 1.06 | 0.12 - 0.43 |
| Brome | 6 | Average | 57.3 | 10.5 | 37.1 | 0.53 | 0.20 |
| | | Range | 46.0 - 67.5 | 8.8 - 12.0 | 26.3 - 46.7 | 0.33 - 0.80 | 0.14 - 0.28 |
| Canola | 13 | Average | 65.3 | 13.9 | 42.3 | 1.23 | 0.31 |
| | | Range | 30.2 - 83.3 | 8.1 - 20.5 | 26.5 - 55.2 | 0.69 - 2.06 | 0.21 - 0.48 |
| Clover (unsp.)* | 141 | Average | 63.5 | 14.7 | 42.6 | 1.39 | 0.21 |
| | | Range | 33.4 - 89.0 | 10.7 - 20.6 | 27.6 - 57.9 | 1.00 - 1.90 | 0.11 - 0.35 |
| Sweet clover | 16 | Average | 64.4 | 16.1 | 39.7 | 1.30 | 0.22 |
| | | Range | 45.0 - 81.5 | 7.8 - 20.5 | 28.1 - 63.0 | 1.04 - 1.71 | 0.01 - 0.33 |
| Clover/grass | 145 | Average | 61.1 | 13.8 | 39.6 | 1.07 | 0.21 |
| | | Range | 34.6 - 85.0 | 7.4 - 21.1 | 25.7 - 56.1 | 0.20 - 1.97 | 0.09 - 0.32 |
| Corn | 203 | Average | 71.2 | 10.0 | 31.2 | 0.28 | 0.23 |
| | | Range | 54.8 - 84.1 | 5.3 - 15.6 | 21.2 - 40.7 | 0.04 - 0.63 | 0.12 - 0.38 |
| Fababeans | 21 | Average | 70.7 | 17.3 | 36.3 | 1.18 | 0.25 |
| | | Range | 54.5 - 85.0 | 13.1 - 22.8 | 24.1 - 45.1 | 1.00 - 1.47 | 0.17 - 0.36 |
| Grass (unsp.)* | 27 | Average | 60.9 | 14.6 | 37.0 | 0.70 | 0.27 |
| | | Range | 32.8 - 80.5 | 8.3 - 31.5 | 21.8 - 48.5 | 0.40 - 1.00 | 0.12 - 0.58 |
| Legume/grass | 660 | Average | 58.2 | 14.3 | 38.2 | 1.23 | 0.23 |
| | | Range | 30.2 - 85.0 | 6.8 - 22.6 | 24.7 - 56.1 | 0.20 - 2.66 | 0.09 - 0.38 |
| Mixed cereal | 93 | Average | 62.1 | 11.0 | 35.8 | 0.48 | 0.26 |
| | | Range | 37.2 - 79.8 | 8.1 - 18.3 | 23.0 - 52.2 | 0.15 - 1.21 | 0.13 - 0.45 |
| Oats | 201 | Average | 62.1 | 10.6 | 36.3 | 0.39 | 0.24 |
| | | Range | 33.8 - 86.0 | 4.3 - 18.8 | 26.1 - 57.1 | 0.07 - 1.01 | 0.10 - 0.38 |
| Sunflower | 6 | Average | 74.5 | 12.2 | 33.9 | 1.29 | 0.21 |
| | | Range | 63.0 - 84.7 | 11.0 - 13.98 | 28.7 - 42.6 | 1.01 - 1.59 | 0.17 - 0.27 |
| Triticale | 40 | Average | 60.3 | 10.4 | 33.1 | 0.31 | 0.24 |
| | | Range | 40.6 - 74.2 | 5.9 - 18.4 | 25.4 - 45.6 | 0.16 - 0.61 | 0.16 - 0.31 |
| Wheat | 29 | Average | 57.0 | 11.2 | 37.8 | 0.25 | 0.24 |
| | | Range | 32.1 - 76.6 | 6.5 - 18.5 | 28.6 - 50.7 | 0.11 - 0.49 | 0.16 - 0.39 |

* unsp. = unspecified
All values are on a moisture-free basis
Source: Soleiman (1987)

Therefore, chopping silage shorter than recommended may lead to reduced animal performance.

## VOLUNTARY CONSUMPTION OF HAYS AND SILAGES

If growing or lactating animals are fed forage-based diets, the amount of forage the animals will voluntarily consume is very important since this consumption will determine the ultimate nutrient intake of the animal.

Once animals become accustomed to the taste of silage, they find it quite palatable, but for the first few days of the feeding period, consumption can be quite low. Even when accustomed to silage, animals will generally eat less dry matter when silage is fed than when the same forage is fed in the fresh form. Also, ruminants will normally consume more dry matter when fed good hay than when fed silage of the same quality. For sheep, the voluntary consumption of forage is decreased more through ensiling than for cattle.

Animals will eat more dry matter from drier silages than from wetter silages (Figure 67). The reasons for this behavior are not completely clear, but it is known that the extra water in the silage is not the explanation. Decreased intake of high moisture silage has been related to the various amines and ammonia produced when protein is degraded and to the formation of other

organic compounds. Also, more total acids are produced with wetter silage, and it has been shown that voluntary intakes can be increased if the acids in these silages are neutralized at the time of feeding.

Voluntary consumption of haylage and silage is increased by reducing the length of chop in the forage to the recommended lengths given above.

FIGURE 67

Livestock have greater daily intake from drier silages than from wetter silages.

## AMOUNT OF SILAGE TO BE FED

Since silage usually contains more than 50 per cent water, animals have to consume more silage than hay to meet their nutritive requirements. In calculating amounts of silage to be fed, the moisture content of the material must be determined. The dry matter content of silage will be essentially the same as the dry matter content of the forages put into silo unless excessive seepage has occurred.

Table 31 shows the hay equivalents of silages with differing moisture contents. This ratio can be used to estimate the amount of silage that should be fed.

## FEEDING SILAGE TO DIFFERENT CLASSES OF LIVESTOCK

All animals consume silage at varying levels (Figure 68). It is very important that **all silage and major feedstuffs be tested for feed quality, including protein, energy and minerals.** The results of the feed tests can then be used to develop a balanced feeding program. These programs are animal specific and farm specific. Contact your local animal nutritionist, feed company or consultant.

**TABLE 31**

**Amount of silage required to provide the equivalent of 1 kg (lb) of 90% dry matter hay**

| Moisture in silage or haylage(%) | Dry matter (%) | kg (or lb) of silage to replace 1 kg (or lb) of hay |
|---|---|---|
| 40 | 60 | 1.5 |
| 45 | 55 | 1.6 |
| 50 | 50 | 1.8 |
| 55 | 45 | 2.0 |
| 60 | 40 | 2.25 |
| 65 | 35 | 2.6 |
| 70 | 30 | 3.0 |
| 75 | 25 | 3.6 |
| 80 | 20 | 4.5 |
| 85 | 15 | 6.0 |

It is also possible to calculate the amount of silage required by using the following method:
(1) Calculate the dry matter (DM) content of silages as: % DM = 100 - % moisture
(2) Calculate amount of silage to feed as: kg DM required X 100 divided by % DM in silage

FIGURE 68

Silage is used in most feedlots.

**Calves less than four months of age:** The diet should not contain large amounts of silage. It tends to cause scouring, and calves will not eat enough of it to meet their nutrient requirements. Some silage will not hurt them. As long as the animals are receiving enough milk, grain, protein, mineral and vitamin supplements to meet most of their nutritional requirements, silage can be fed as the only roughage source.

**Growing calves from five to ten months of age:** Silage can be fed as the major constituent of the ration. There is, however, a need for grain and other supplements to provide the animals with enough nutrients to gain at the minimum rate required for optimal productivity and economy. It is well to remember, though, that animals will normally eat less dry matter as silage than they will as hay. Therefore, the amount of grain in the diet may have to be increased slightly when silage is fed. This consideration is of particular importance when high moisture silage is fed.

**Fattening cattle:** Silage is a very good feedstuff to include in feedlot diets since it tends to reduce the incidence of bloat. For the first couple of days in the feedlot, hay is the preferred form of forage for cattle. Some of the animals may not be used to silage. Resulting low feed intakes can contribute to an increased incidence of sickness and poor performance at this time.

**Replacement heifers over a year of age:** These can be fed a silage-based diet without grain supplementation provided the silage is of good quality.

**Mature beef cows:** Silage can be fed as the only source of energy and protein if it is good quality silage. Only in extreme cases will protein supplementation be required.

In all-forage diets, however, trace mineral supplementation should be provided. Calcium and phosphorus supplementation may also be required. Particular attention should be paid to the mineral supplementation programs for beef cows consuming rations high in cereal silage. Cereal silage may be low in calcium and magnesium, and high in potassium, creating the potential for a winter tetany problem. Proper mineral programs are imperative. Vitamin A, D and E supplementation of silage diets is required in the winter.

When good quality silage is available, it may be advisable to limit the amount of silage fed daily and allow the cows to fill up on straw. This approach will result in a less costly ration and will prevent the cows from getting too fat. In cold weather, and as the time of calving gets closer, the amount of silage fed can be increased, and if necessary, grain can be added to the diet.

**Beef cows with calves:** Silage made from high quality forage with less than 70 per cent moisture will usually be adequate without supplemental grain for beef cows nursing calves. If the silage contains more than 70 per cent moisture, or if it is of only average to poor quality, or if the level of milk production in the cows is high, supplemental grain or good quality hay will be required. If silage is being considered as the main feedstuff for nursing cows, be sure to have the forage tested since protein and other nutrient deficiencies are quite possible.

**Breeding bulls:** Feeding silage does not affect the quantity or quality of semen produced by bulls. Therefore, silage can form the complete ration for bulls if mineral and vitamin supplementation are available. Supplemental protein will often be required when grass silages are fed. If the condition of a bull is poor, or the silage contains more than 70 per cent moisture, or the silage is of poor quality, supplemental good quality hay or grain should be considered.

**Milking dairy cows:** Silage is a good feed for milking cows if attention is paid to harvesting the forage at the proper stage of maturity.

Silage has been used successfully as the only forage source in the diet of milking cows. However, diets based on silage as the only forage may contribute to a low butterfat test. This outcome appears to be caused by the short chop length common in silage, which results in a reduction in the "effective fibre" content of the ration. If this is a problem, various corrective measures can be taken including the addition of long or coarsely chopped hay in the ration. Increasing the length of cut may also be beneficial in higher moisture silages.

Problems can occur with off-flavored milk when cows are fed silage just prior to milking, especially grass silage that contains high levels of butyric acid. The off-flavor can appear if cows breathe the odor. If this situation occurs, feeding the offending silage after milking may reduce or eliminate the problem.

**Sheep:** Some time is required for sheep to get used to the taste of silage; thus, it should be introduced gradually into a diet over a two-week period.

Silage can be fed to young growing lambs, but grain, protein, mineral and vitamin supplements will be required to achieve acceptable growth rates.

Silage can provide the only roughage source for mature sheep once they get used to the taste. Some ewes, however, will not eat enough silage to meet their nutritional requirements, especially if the silage has a low nutrient content or is too wet. This situation is particularly true for ewes carrying twin lambs since rumen capacity is reduced because space in the abdominal cavity is taken up by the developing lambs. Therefore, silage of low nutrient content or excessively wet silage should be supplemented with grain or good quality hay.

**Horses**: Silage is not usually thought of as a feed for horses, but it can be fed as the only roughage source in the diet of mature horses. Care should be taken to make sure the silage has not become mouldy while in the silo or after it has been removed from the silo. Mouldy feed should not be fed to horses at any time.

## SPECIAL PROBLEMS RELATED TO FEEDING

For information on symptoms and diagnosis of the health problems listed below, contact your veterinarian.

**Tetany**: Tetany is a metabolic disease caused by lower than normal blood magnesium (Mg) levels. It is often seen in cows in late pregnancy or after calving. The first sign of this disease in a beef herd is often a dead cow with marks of struggling or paddling on the ground around her head and legs. Cows ill with tetany are often excitable or "flighty," they appear uncoordinated and may be trembling or staggering. Occasionally, affected cows look like those with milk fever in that they are down, very quiet and unable to get up.

High levels of potassium in silage can reduce the amount of magnesium absorbed from the ration. The potassium content of forages is usually 1.5 percent to 1.9 percent (100% dry matter basis). Drought or dry growing conditions and regions with acidic soils (low pH) contribute to the accumulation of potassium in plants, especially cereal crops. Alfalfa can also accumulate high levels of potassium. This imbalance of minerals in silage is easily corrected with an effective mineral program. Analyze all silage for a general mineral profile, and work with a nutritionist to choose the mineral program suited to your management regime.

**Ketosis**: There can be an increased incidence of ketosis in dairy cows fed silage as compared to cows fed hay. This problem is more likely to occur when poorly fermented silage with high levels of butyric acid is fed since butyric acid is metabolized to ketone bodies in the animal.

There may also be problems with reduced intakes, which can cause ketosis, if lactating cows are switched from a hay to a silage diet too rapidly. Extra care should therefore be taken when lactating cows are switched to a silage-based diet, especially when they are not accustomed to silage.

Ketosis has also been reported to be a predisposing factor to pregnancy toxemia in pregnant ewes.

**Nitrate poisoning**: Nitrate-nitrite poisoning has been reported in animals fed silage. The amount of nitrate present in silage is always less than that which was present in the original crop. From 30 to 70 per cent or more of the nitrate in the original forage is degraded in the ensiling process. This result, however, does not guarantee that nitrate toxicity will not occur when a high nitrate-containing forage is conserved as silage. It appears that little degradation of nitrates occurs when the pH of the silage drops below 5. There is more degradation of nitrates in silage that has undergone an undesirable type of fermentation than in silage in which a desirable type of fermentation has taken place.

Where nitrate poisoning could be a problem, it is advisable to test for nitrates. Most feed testing laboratories do nitrate tests quickly and inexpensively.

**Listeriosis**: Listeriosis is a disease caused by the bacterium *Listeria monocytogenes*. The disease is commonly associated with silage, but it can occur when silage is not being fed.

Listeriosis is also known as circling disease. Affected animals crowd into a corner, lean against fences and move in circles when walking. The disease also affects the nervous system. Lack of coordination, high temperatures, lack of appetite, blindness, salivation and paralysis of jaw muscles also occur. The disease is usually fatal, especially with sheep, and animals that survive have brain damage. Usually no more than 8 to 10 per cent of cattle are affected. The organism can also cause abortion in the third trimester of pregnancy.

Bacteria causing listeriosis are present on the vegetation and grow in the ensiling process only if the pH of the silage is above 4.2. The disease is more common in cold weather and when the animal undergoes stress. Nutrient deficiencies also may trigger the disease.

*Listeria monocytogenes* organisms also infect man, so precautions should be taken when handling an aborted fetus or if tasting silage to estimate quality.

**Mouldy Silage:** Mouldy silage is caused by fungi that grow readily on wet material when it is exposed to air. Under certain circumstances, these organisms may produce mycotoxins that have adverse effects on animals. Mouldy silage can cause severe diarrhea, loss of appetite, abortion, muscular tremors, pneumonia, changes in the lung, allergic reactions and death. Mycotoxins can also affect the microorganisms in the rumen. However in most instances, small amounts of moulds will not cause problems when fed to livestock.

To prevent mouldy silage, follow proper ensiling procedures.

**Botulism:** The microorganism *Clostridium botulinum* can grow in silage under conditions that favor clostridial organisms. Symptoms of this disease include paralysis of the throat, profuse salivation, lack of muscular coordination and often death. Cattle are less susceptible to botulism than horses since the toxin responsible for the problem is rapidly inactivated by ruminal microbes.

**Dicoumarol poisoning:** Sweet clover contains varying amounts of coumarin. This chemical is often converted to dicoumarol in mouldy feeds. Dicoumarol interferes with the blood clotting mechanism in animals and can result in excessive bleeding, anemia and death when fed to livestock.

Low coumarin varieties of both yellow and white sweet clover are now available, but older varieties are high in coumarin.

If sweet clover silage is being made, care should be taken to avoid mould formation by carefully covering and sealing the silo. Also, when feeding silage, discard any mouldy portions of the silage. It is often advisable to limit the amount of sweet clover in the diet, particularly before the calving or lambing period.

# Chapter 8: **Costs of Silage Production**

The silage system chosen should make economic sense. Producers need to pencil out their costs versus the benefits a silage system can offer their operation. Harvesting, storage and transportation all add costs, as do additives and feeding equipment. Silage can be priced different ways according to various factors.

Silage making offers increased flexibility and cost savings over dry forage systems with few economic disadvantages (Table 32).

**TABLE 32**
**Silage production in comparison to dry forage systems**

| Advantages | Disadvantages |
|---|---|
| • Harvest weather flexibility<br>• Lower field losses<br>• Use a wider range of crops and other feed sources<br>• Salvaging damaged or weedy crops<br>• Potentially fewer feeding losses<br>• Ability to handle large volumes quickly | • Higher capital and labor cost<br>• Limited transportation distance<br>• Potentially higher storage losses |

Choosing to harvest and store forage as silage is often an effort to increase handling efficiency of feeds, store salvaged crops or improve the quality of forages consumed by livestock. A well-managed silage system will maximize the intake of nutrients per harvested acre at the lowest possible cost.

## SELECTING A FORAGE SYSTEM

The benefits of a forage harvest, storage and feeding system are best evaluated as the saleable product(s), milk or meat, of the animals consuming the forage. The ideal silage system for a farm or ranch is one that allows the job of forage harvesting, storing and feeding to be done in a timely and effective way resulting in the least cost per unit of feed used by the animals. The system that provides adequate efficiency of harvesting and storing with a low cost per ton of feed depends on the volume and quality of feed needed, the transportation distance and the type of crops available.

There is a great variation in the amount of feed that will be spoiled or wasted using different systems, depending on crop conditions and management practices. Most systems can be improved to lower costs, but careful consideration of all the implications is important.

The partial budget in Table 33 shows an example of how the decision to change from a dry hay system using round bales to a chopped silage system in a bunker silo could be evaluated. The left hand column describes the added costs of silage making, which include field operations, hauling, packing and covering the bunker, and the value of feed dry matter losses in the silage system. Decreased costs of the change to silage making are baling, hauling the bales from the field, twine and the dry matter losses for the hay system. In this example, the difference between the total added costs and total decreased costs of $8.00 per acre favors the change to making silage. The higher costs of labor, equipment and materials for the silage system are more than offset by the reduction in the value of dry matter losses. The partial budget can be used to evaluate the feasibility of any change to a feed production and management system.

**TABLE 33**
**Partial budget for changing harvest system from baling dry hay to chopped silage in a bunker[1]**

| Added Costs | $/ac | Decreased Costs | $/ac |
|---|---|---|---|
| Chopping, hauling and packing | $ 74.00 | Baling and hauling | $ 60.00 |
| Plastic cover | $ 10.00 | Twine | $ 3.00 |
| Forage losses with silage (15% dry matter losses) | $ 40.00 | Forage losses with hay (25% dry matter losses | $ 69.00 |
| Total added costs | $ 124.00 | Total decreased costs | $ 132.00 |
| | | Excess returns for silage system | $ 8.00 |

[1]Based on 4 tons yield at 65% moisture and having a pre-harvest standing crop value of $17.50 per ton
Machine cost estimates from Alberta Agriculture, Food and Rural Development (2002)

## HARVESTING COSTS

In most silage systems, field chopping operations are the most capital and labor intensive part. High capacity, self-propelled forage harvesters are very efficient when crop yields are high and the silage making season is long. Pull-type forage harvesters have lower capacity making them more cost effective for situations where crops are lighter and fewer acres are harvested annually. Balers suitable for making silage bales are somewhat more costly than regular balers but can also be used for baling dry feed, which extends their season of use and lowers the annual fixed cost.

Figure 69 shows the effect of increased tonnage and harvesting days on the harvest cost per ton for three machines options. As the number of tons harvested increases, the cost per ton harvested falls due to the dilution of fixed costs. For each machine and harvest season, there is a limit to the number of days that harvesting can occur.

If any of the silage systems was only used to process 500 dry matter tons of silage per year, the fixed cost would be prohibitive. For this reason, consider hiring a custom operator to make silage in small quantities. Custom operators with many hours of annual machine use have lower fixed costs per ton and can offer competitive rates.

## STORAGE AND TRANSPORTATION COSTS

### Hauling from field to storage

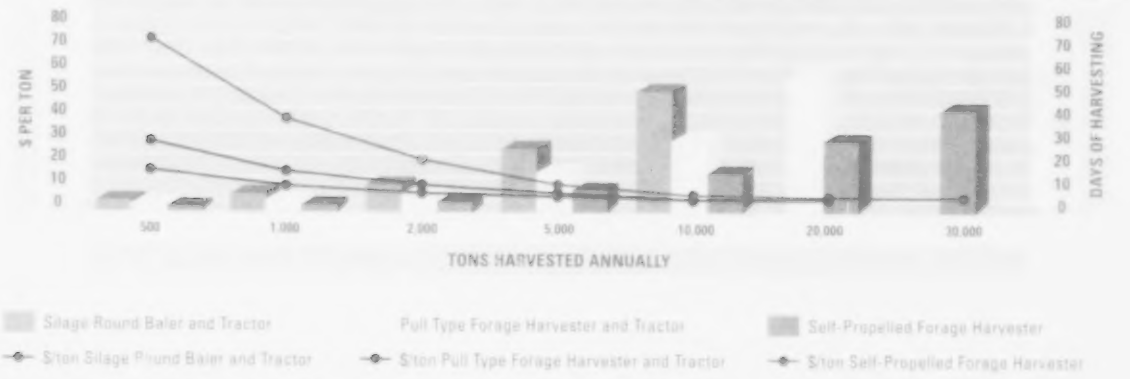
Because of the high moisture content of silage, feasible transportation distance is limited.

Trucking requirements from field to storage site are affected by hauling distance, travel speed, loading and unloading time. On short hauls (less than 5 km or 3 miles), a single truck can keep up to a medium capacity forage harvester when a dump wagon is used. Longer hauls, higher capacity harvesters, or not using a dump wagon means adding more trucks to avoid waiting time in the field or at the storage site. For example if hauling 8 km (5 miles) requires adding one truck at $80 per hour and that truck hauls 40 tonnes per hour of 35 per cent dry matter silage, transportation costs are increased by $2 per tonne on a wet basis ($5.71 per tonne at 100% dry matter).

In a bale silage operation, the number of times a bale is handled between the baler and the storage location can quickly increase cost. Using specialized trucks or trailers to haul silage bales to the storage site can reduce the labor and equipment needs, and improve overall efficiency of the operation.

**FIGURE 69**

**Effect of increasing annual tonnage on days of harvest and cost per ton harvested**




Source: Adapted from Alberta Agriculture, Food and Rural Development *Farm Operations Cost Guide* (2002)

## Storage structures and equipment

There is a wide range in the capital costs and annual operating costs of storage structures. The choice of a structure depends on the volume of silage handled, quality and uniformity of silage needed, and need for flexibility in annual tonnage. Evaluate options by comparing them on a per ton basis after storage losses. For example, a bunker silo with earthen walls and floor would have a much lower initial cost and annual operating cost than an oxygen-limiting tower silo, but it would also have higher nutrient and dry matter losses.

### Bunker silo packing and covering

Proper packing is a critical step in silage making. Although it is tempting to fill the bunker fast and not spend adequate time packing, the cost of packing properly is not great when compared to potential losses throughout a poorly packed pile. When silage is delivered to the pit at the rate of 80 tons per hour, the cost of extra packing with a four-wheel drive tractor is about $1 per ton wet basis ($2.85 at 100% dry matter of 35% dry matter silage). If the silage is valued at $35 per ton (in storage), less than a 3 percent reduction in losses is needed to pay for the extra cost of packing.

Does it always pay to cover silage with an oxygen-limiting layer? In the case of a plastic cover and a crop that has the potential to ensile, the answer is yes. Other oxygen-limiting options must be considered more carefully in terms of their cost and their potential to exclude oxygen initially and throughout the storage period.

Research has shown that dry matter losses in the top 1 m (3.3 ft) of silage are 20 per cent for covered silage and 50 per cent for uncovered (Bolsen et al. 1999). The payback of silage saved compared to the cost of covering will vary with the value of silage, the depth of the bunker, the cost of the covering material and the labor to install it.

Table 34 shows an example of the value of dry matter losses at four prices of silage for covered and uncovered bunker silos. The difference in losses would also be the breakeven point for the cost of covering the bunker. As the depth of the bunker increases, the benefit to covering is diminished when measured by losses in the top 1 m.

## SILAGE ADDITIVES

Silage additives can improve forage quality while increasing harvest flexibility. However they do not provide an economic benefit in all circumstances. The cost of the treatment may be greater than the increase in the value of the end product. When the saleable end product is milk and the quantity produced depends on a consistent high quality feed, there is a better opportunity for the cost of the additive to be recovered.

The opportunity to recover the cost of the additive also depends on crop potential. A crop like alfalfa that has high levels of protein and energy, but is more difficult to ensile is a better candidate for using an additive than is barley, which is easy to ensile. Harvesting in the soft dough stage places an emphasis on tonnage rather than nutrient density, and the resulting barley silage is less likely to benefit from the expense of an additive.

**TABLE 34**
**Value of dry matter loss from top 1 m of a silage bunker***

| | Value of loss ($/tonne as fed) | | | |
|---|---|---|---|---|
| **Silage price/tonne** | **$ 25** | **$ 35** | **$ 45** | **$ 55** |
| Covered bunker silo, 20% dry matter loss | $ 680 | $ 952 | $ 1,224 | $ 1,497 |
| Uncovered bunker silo, 50% dry matter loss | $ 1,701 | $ 2,381 | $ 3,061 | $ 3,741 |
| **Difference in cost or breakeven cost for covering** | **$ 1,021** | **$ 1,429** | **$ 1,837** | **$ 2,244** |

*35% dry matter silage at 42 lb/ft³, and bunker width is 50 ft and length is 150 ft
Source: Adapted from Bolsen et al. (1999)

## FEEDING EQUIPMENT AND SYSTEMS

Silage systems that are managed to limit waste at feeding will often outperform other forage systems in consistency of intake, minimal losses and speed of delivery. Chopped silage is an efficient way to deliver a high quality diet to a large number of animals each day. Using modern loaders and feed mixing trucks, one laborer can deliver feed to thousands of cattle daily in a feedlot setting (Figures 70). Self-feeding from a silage pile, bags or bales using an electric wire or headgate equipment (Figure 59) to limit feed consumption is perhaps the least costly way of feeding silage; however, the waste can be quite high if not managed correctly.

For a feed delivery system to be economical, it should cost less than the value of the feed that would be lost by using an alternative feed system. When the lost value of the waste is included, the self-feeding system could be more costly than a well-managed mechanized system.

## SILAGE PRICING

Pricing of silage is challenging because of limited price reporting, wide variation in quality and the many forms of silage. Silage prices are not often set in a publicly traded market but are determined by local supply and demand and prices of alternate feeds. The high moisture content of silage restricts transportation distance, limiting supply and demand relationships to conditions of the local market.

Significant factors that affect silage price:

- moisture content
- potential quality
- location relative to:
  - storage site
  - feeding site
- processing or harvest stage

The moisture level of the silage has a large effect on the price. Water is a critical ingredient for the ensiling process and for cattle consuming the silage, but it is not considered to contribute any monetary value to the silage. In fact, higher moisture silages are more expensive to handle when considered on a dry matter basis. It is the dry matter portion of the silage that has feeding value; therefore, all silages of equal feed value would be equal in price at a 100 per cent dry matter basis. As moisture content increases, dry matter content decreases and so does the as-fed basis price. From the example in Table 35, increasing the moisture content 10 percentage points from 60 to 70 per cent lowers the price by 25 per cent.

**TABLE 35**
**Example of the as-fed price of silage as influenced by moisture content**

| Moisture content (%) | Silage price ($ per tonne as fed) | | | | | |
|---|---|---|---|---|---|---|
| 50 | $ 18.75 | $ 25.00 | $ 31.25 | $ 37.50 | $ 43.75 | $ 50.00 |
| 55 | $ 16.88 | $ 22.50 | $ 28.13 | $ 33.75 | $ 39.38 | $ 45.00 |
| 60* | $ 15.00 | $ 20.00 | $ 25.00 | $ 30.00 | $ 35.00 | $ 40.00 |
| 65 | $ 13.13 | $ 17.50 | $ 21.88 | $ 26.25 | $ 30.63 | $ 35.00 |
| 70 | $ 11.25 | $ 15.00 | $ 18.75 | $ 22.50 | $ 26.25 | $ 30.00 |

*Base moisture content of silage is 60%.

**FIGURE 70**

The cost of machinery must be worked into the equation.

The price conversion factors are in column C of Table 36 and can be used to calculate an actual value for silages of differing moisture/dry matter content where the initial price is based on 65% moisture or 35% dry matter. After determining that the actual moisture/dry matter content of the silage is different from 65%/35%, find the actual value in columns A and B, and multiply the base value by the conversion factor in column C. Sample Calculation #1 shows how to use Table 36. If the base price is set at a moisture/dry matter content different than 65%/35%, the price can be converted using the steps outlined in Calculation #2.

Making silage involves expensive transportation and processing as well as losses to handling, ensiling and storage. The stage of production or use at which the silage is priced affects its value. The standing crop has the lowest per ton cost, and the cost increases with each harvest, storage and handling operation and with each loss. If the costs become higher than the value of an alternative feed, the seller will not be able to recover the extra costs by raising the price. In most cases, only handling costs are recovered, and the costs associated with storage losses are absorbed by the cropping enterprise.

**TABLE 36**

**Silage Price Conversion Chart**

| Base Price Moisture Content | 65% | |
|---|---|---|
| Base Price Dry Matter Content | 35% | |
| A | B | C |
| % Moisture | % Dry Matter | Price Conversion Factor |
| 45 | 55 | 1.6714 |
| 46 | 54 | 1.5429 |
| 47 | 53 | 1.5143 |
| 48 | 52 | 1.4857 |
| 49 | 51 | 1.4571 |
| 50 | 50 | 1.4286 |
| 51 | 49 | 1.4000 |
| 52 | 48 | 1.3714 |
| 53 | 47 | 1.3429 |
| 54 | 46 | 1.3143 |
| 55 | 45 | 1.2857 |
| 56 | 44 | 1.2571 |
| 57 | 43 | 1.2286 |
| 58 | 42 | 1.2000 |
| 59 | 41 | 1.1714 |
| 60 | 40 | 1.1429 |
| 61 | 39 | 1.1143 |
| 62 | 38 | 1.0857 |
| 63 | 37 | 1.0571 |
| 64 | 36 | 1.0286 |
| **65** | **35** | **1.0000** |
| 66 | 34 | 0.9714 |
| 67 | 33 | 0.9429 |
| 68 | 32 | 0.9143 |
| 69 | 31 | 0.8857 |
| 70 | 30 | 0.8571 |

**CALCULATION #1**

**Example using Table 36:**

Alfalfa silage is priced at $30 per ton as fed with a moisture/dry matter content of 65%/35% and the actual moisture/dry matter content of the silage is 58%/42%.

$30 per ton (base price) X 1.2000 (from column C) = $36 per ton @ 58% moisture

**CALCULATION #2**

1. base price of silage as fed / dry matter % at base price = base price at 100% dry matter

2. base price at 100% dry matter X actual dry matter of silage = adjusted price

**Example:**

Barley silage is priced at $30 per ton with a moisture/dry matter content of 60%/40% and the actual moisture/dry matter content of the silage is 63%/37%.

1. $30 per ton as fed / 0.4 dry matter = $75 per ton @ 100% dry matter

2. $75 per ton @ 100% dry matter X 0.37 dry matter = $27.75 per ton @ 37% dry matter

There are a number of ways to arrive at a price for silage. It can be valued according to:

- the basis of feeding value by comparing a similar or alternative feed source
- the price of the alternative
- adjustment for differences in
    - moisture
    - location
    - quality
    - handling costs
    - waste
- an alternative use for the crop, i.e., harvesting for grain
    - projected yield and price of grain
    - value of straw
    - cost of harvest (combining, baling and hauling)
    - estimate of risk to the crop from silage stage until maturity
    - benefits to early harvest such as weed control, second crop, etc.
- the cost of production
    - total value of seed, fertilizer, pesticide, labor, equipment, land rent and profit

The preferred method of pricing will vary depending on how the price is to be used. The cost of production approach is useful for enterprise budgeting or for determining the break- even price as seller. Comparing to an alternative use for the crop helps the crop producer choose between harvesting for silage or waiting to harvest for grain. The feed value approach helps the silage buyer evaluate the silage against other feed options.

# References

## GENERAL

For more information on any of the topics discussed in the manual, go to:

- Alberta Agriculture, Food and Rural Development's website at **http://www.agric.gov.ab.ca**
- Forage Beef website at **www.foragebeef.ca**

## ENSILING PROCESS


Gallagher, D.W. and K.R. Stevenson. 1976. Heat Damage in Hay-Crop Silage. Ontario Ministry of Agriculture and Food. Factsheet No. 76-007.

McDonald, P. 1973. The Ensilage Process. Page 33. *In*: Chemistry and Biochemistry of Herbage. G.W. Butler and R.W. Bailey (eds). Academic Press, New York.

McDonald, P. 1981. The Biochemistry of Silage. John Wiley & Sons, Toronto.

Morgan, C.A., R.A. Edwards and P. McDonald. 1980. Intake and Metabolism Studies with Fresh and Wilted Silages (Cattle and Sheep). Journal of Agricultural Science, Cambridge, 94: 287-298.

Smith, D. 1973. The Nonstructural Carbohydrates. Page 105. *In*: Chemistry and Biochemistry of Herbage. Vol. I. G.W. Butler and R.W. Bailey (eds). Academic Press, New York.


## CROPS FOR SILAGE


Aasen, A. and V. Baron. 1993. Winter Cereals for Pasture. Alberta Agriculture Agdex 133/20-1.

Aasen, A., R. Corbett, G. Mathison and E. Strytveen. 1992. Field Pea Silage as a Replacement for Alfalfa in a Dairy Ration. Final Report, Project 92-F003-5. Farming for the Future, On Farm Demonstration.

Agriculture Canada. 1984. Annual Forage Crops for Alberta. Farming for the Future Project No. 78-0181, Agriculture Canada, Research Branch.

AHRC (Alberta Special Crops and Horticultural Research Centre). 1984. Progress Report on Trials Involving Annual Forages 1983 and Summary of Trials from 1979 to 1983. Alberta Special Crops and Horticultural Research Centre, Pamphlet 84-6, p. 53.

Alberta Corn Committee. 1982. Corn Production and Utilization in Alberta. Alberta Agriculture, Agdex 111/20-1.

Baron, V. et al. 2000. Advanced Dairy Technology 2000. Vol. 12, pages 351 - 368, Western Dairy Congress.

Malhi, S.S., D.H. Laverty, J.T. Harapiak, L.M. Kryzanowski and D.C. Penney. 1993. Fertilizer Management for Forage Crops in Central Alberta. Agriculture Canada, Research Branch, Technical Bulletin 1993-3E.


## SILAGE ADDITIVES


McDonald, P. 1981. The Biochemistry of Silage. John Wiley & Sons, Toronto.

Woolford, M.K. 1984. The Silage Fermentation. Marcel Dekker, Inc. New York.

## SILOS

Agriculture Canada. Grass, Legume and Cereal Silages for Ruminants. Agriculture Canada Publication 1786E.

Agriculture Canada. Silo Types and Their Use. Agriculture Canada. Canadex 120.60.

Bellman, H.E. 1982. Selection and Use of Oxygen-limiting Silos. Agriculture Canada Publication 1728E.

Canada Plan Service (leaflets from 7000 Series: Grain, Forage and Feed Storage, available at http://www.cps.gov.on.ca/english/gs7000/grain.htm).

Darby, D.E., and J.C. Jofriet. 1993. Density of Silage in Horizontal Silos. Canadian Agricultural Engineering. Vol. 35, No. 4, pages 275-280.

Hoglund, C.R. 1964. Comparative Losses and Feeding Values of Alfalfa and Corn Silage Crops when Harvested at Different Moisture Levels and Stored in Gastight and Conventional Tower Silos. Michigan State University, Agricultural Economics Publication 947.

McIsaac and Lovering. A Model for Estimating Silo Losses and Costs. Canadian Farm Economics. Vol. 15, No. 5.

Muck, R.E. and B.J. Holmes. 2001. Factors Influencing Density and Losses in Pressed Bag Silos. 2001 ASAE Annual International Meeting, Sacramento, California, July 30 - August 1, 2001.

Ontario Ministry of Agriculture and Food. Tower Silo Capacities. Ontario Ministry of Agriculture and Food. Agdex 100/732.

Robinson, P.H., J.J. Kennelly and G.W. Mathison. 1987. Influence of Silo Bag Type on Silage Quality. Pages 54-57 *In:* 66th Annual Feeders Day Report, 1987. Agriculture and Forestry Bulletin, University of Alberta.

Turnbull, J.E. 1973. Design of Footings for Concrete Tower Silos.

## EVALUATING SILAGE QUALITY

Rohweder, D.A., R.F. Barnes and Neal Jorgensen. 1978. Proposed Hay Grading Standards Based on Laboratory Analysis for Evaluating Hay. Journal of Animal Science, Vol. 47, page 747.

## FEEDING VALUE OF SILAGES

Soita, H.W., D.A. Christensen, and J.J. McKinnon. 2000. Influence of Particle Size on the Effectiveness of the Fibre in Barley Silage. Journal of Dairy Science, Vol. 83, No. 10, pages 2295-2300.

Sudweeks, E.M., L.O. Ely, D.R. Mertens, and L.R. Sisk. 1975. Assessing Minimum Amounts and Form of Roughages in Ruminant Diets. Journal of Animal Science, Vol. 53, pages 1406-1410.

Suleiman, A.I.H. 1987. Average Analyses of Alberta Feeds 1976-1986. Alberta Agriculture, Agdex 100/81-6.

## COSTS OF SILAGE PRODUCTION

Bolsen et al. 1999. Silage Management and Its Economic Impact for the Dairy Industry: Two Key Factors. Pages 7-11 *In:* Four State Applied Nutrition and Management Conference Proceedings, La Crosse Wisconsin.

Alberta Agriculture, Food and Rural Development. 2002. Farm Operations Cost Guide. Alberta Agriculture, Food and Rural Development. Agdex 825-1.

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## UNIT CONVERSIONS

1 kilogram (kg) = 2.205 pounds (lb)
1 kilometre (km) = 1,000 metres (m) = 3,281 feet (ft) = 0.6214 miles
1 centimetre = 0.39 inches
1 $m^3$ = 1,000 litres (L) = 220 gallons (Imperial)
1 hectare (ha) = 10,000 $m^2$ = 107,639 $ft^2$ = 2.471 acres (ac)
to convert lb/ac to kg/ha multiply by 1.12 (therefore 1 lb/ac = 1.12 kg/ha)
to convert kg/ha to lb/ac multiply by 0.893 (therefore 1 kg/ha = 0.893 lb/ac)
1 tonne = 1,000 kg = 2,205 lb = 1.1025 ton (short)

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